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HEAT-TRANSFER TESTS OF THE NASA/ROCKWELL INTERNATIONAL SPACE SHUTTLE ORBITER (OH-84B, IH-102, AND OH-105)

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ARO, Inc.

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ARNOLD ENGINEERING DEVELOPMENT CENTER
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AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

NOTICES

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FOR THE COMMANDER

James D Sanders

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Heat transfer tests were conducted on two 0.0175 scale and one 0.04 scale models of the space shuttle orbiter using the thin-skin thermocouple technique. Data were recorded at Mach numbers 3 and 4 in the AEDC-VKF Supersonic Wind Tunnel A and at Mach 8 in the Hypersonic Tunnel B. Ten model configurations were tested including each orbiter model and the two 0.0175 scale models integrated with the external tank and both solid rocket boosters. The objective of the test was to obtain heating data in regions of the orbiter where no previous data exist or where data extrapolation was not feasible. The model angle of

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attack ranged from -40 to 40 degrees with yaw angles varying from -15 to 10 degrees.

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NOMENCLATURE

a_1,a_2,a_3	Denote constant terms used to calculate R, (see Eq. 5)
ALPHA-MODEL, ALPHA	Model angle of attack, deg
ALPHA-PREBEND	Sting prebend angle, deg
ALPHA-SECTOR	Tunnel sector angle, deg
B	Model wing span (see Fig. 4), in.
BV	Height of model vertical tail (see Fig. 4), in.
b	Model skin thickness, in. or ft as noted
C	Local chord of wing or vertical tail (see Fig. 4), in.
CONFIG	Code used to define model configuration
CONSTANT SET, CON SET	The set of thermocouples recorded during a tunnel injection (see Table 5)
COORD1	First thermocouple location coordinate selected from Table 5 to appear on tabulated data
COORD2	Second thermocouple location coordinate selected from Table 5 to appear on tabulated data
c_p	Model skin material specific heat, Btu/lbm°R
C.R.	Center of rotation (see Fig. 8)
DELTAE	Elevon deflection angle, deg
DELTASB	Speed brake deflection angle, deg
DELTBF	Body flap deflection angle, deg
DTWDT	Time rate of change of wall temperature, °R/sec
GROUP	Data identification number
HREF, HREF-FR	Reference heat-transfer coefficient based on Fay and Riddell theory. See Appendix III
H(RTO)	Heat-transfer coefficient based on RTO, Btu/ft^2-sec-°R
H(TO)	Heat-transfer coefficient based on TO (see Eq. 1), Btu/ft^2-sec-°R
H(0.9 TO)	Heat-transfer coefficient based on 0.9 TO, Btu/ft^2-sec-°R
H(0.95 TO)	Heat-transfer coefficient based on 0.95 TO, Btu/ft^2-sec-°R

L	Reference length (see Fig. 4)
MACH NO.	Free-stream Mach number
MODEL	Model configuration
MU-INF	Free stream viscosity, lbf-sec/ft^2
MUO	Viscosity conditions based on stagnation temperature, lbf-sec/ft^2
PO	Tunnel stilling chamber pressure, psia
PO2	Stagnation pressure downstream of a normal shock, psia
P-INF	Free-stream static pressure, psia
QDOT	Heat-transfer rate, $(w\ b\ c_p)$ (DTWDT), Btu/ft^2-sec
Q-INF	Free-stream dynamic pressure, psia
R	Analytical temperature ratio, TAW/TO (see Eq. 5)
RE/FT	Free-stream Reynolds number
RHO-INF	Free-stream density, lbm/ft^3
RN	Reference nose radius, (0.0175 ft or 0.04 ft, determined by model scale)
ROLL-SECTOR	Tunnel sector roll position, deg
STFR	Stanton number based on HREF (see Appendix III)
SWITCH POSITION	Designates the position of the thermocouple selector switch
t	Time from start of model injection cycle, sec
t_i	Time when initial model wall temperature was recorded before model injection, sec
TAW	Computed adiabatic wall temperature, °R
TC NO	Thermocouple number
T-INF	Free-stream temperature, °R
TO	Tunnel stilling chamber temperature, °R
TW	Model wall temperature at midpoint of data interval, °R

TW_i	Initial model wall temperature before injection, °R
V-INF	Free-stream velocity, ft/sec
w	Model skin material density, lbm/ft^3
X	Model scale axial coordinate from model nose or leading edge of wing or vertical tail (see Fig. 4 and 7), in.
X_o	Full scale axial coordinate from a point 235 in. ahead of the orbiter nose, (see Fig. 7) in.
X/L	Thermocouple axial location as a ratio of model length from model nose tip
XN	Model scale axial coordinate of nozzle (see Fig. 9j), in.
Y	Model scale lateral coordinate (see Fig. 4), in.
YAW	Yaw angle of model, deg
Y_o	Full scale lateral coordinate, in.
Z	Model scale vertical coordinate (see Fig. 4), in.
Z_o	Full scale vertical coordinate, in.
α	Angle of attack, deg
ε	Local model surface deflection angle (see Eq. 5), deg
ϕ	Radial angle of thermocouple in model coordinates (see Fig. 4 and 7), deg
ϕ_N	Radial angle of thermocouple on nozzle (see Fig. 9j), deg
ψ	Side-slip angle, deg

1.0 INTRODUCTION

The work reported herein was conducted at the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), by ARO, Inc., AEDC Division (a Sverdrup Corporation Company), contract operator of AEDC, AFSC, Arnold Air Force Station, Tennessee. The work was sponsored by the Johnson Space Center (NASA-JSC(ES3)), Houston, Texas, under Program Element 921E-01. Rockwell International (RI), Space Division, Downey, California was responsible for test planning and data analysis. The project monitor for NASA-JSC(ES3) was Mrs. Dorothy B. Lee and the test engineer for Rockwell International was Mr. Jim Foust.

The test was conducted in both the 40-in. Supersonic Wind Tunnel (A) and the 50-in.-diam Hypersonic Wind Tunnel (B) at the von Karman Gas Dynamics Facility (VKF) during the period May 2-23, 1979, under ARO Project Number V41B-67. Data were recorded at Mach numbers 3 and 4 in Tunnel A and Mach 8 in Tunnel B for nominal Reynolds numbers ranging from 0.5×10^6 to 4.0×10^6 per foot. The nominal model angles of attack ranged from -40 to 40 degrees with model yaw angles varying from -15 to 10 degrees. All data measurements were obtained from three space shuttle orbiter models designated; (1) 56-Ø (0.0175 scale), (2) 60-Ø (0.0175 scale), and (3) 83-Ø (0.04 scale). The three models were installed in a total of ten configurations during the test.

This test was a combination of three NASA/Rockwell tests designated OH-84B, OH-105, and IH-102. The objective of these tests was to obtain heating data in regions of the space shuttle orbiter where no previous data existed or where data extrapolation was not feasible. An additional objective of the OH-105 test was to obtain orbiter heating data for the contingency abort trajectory.

Inquiries to obtain copies of the test data should be directed to NASA-JSC(ES3), Houston, Texas 77058. A microfilm record has been retained in the VKF at AEDC.

2.0 APPARATUS

2.1 TEST FACILITIES

Tunnels A and B (Figs. 1 and 2, Appendix A) are continuous, closed-circuit, variable density wind tunnels. Tunnel A has an automatically driven flexible-plate-type nozzle and a 40- by 40-in. test section. The tunnel can be operated at Mach numbers from 1.5 to 6 at maximum stagnation pressures from 29 to 200 psia, respectively, and stagnation temperatures up to 750°R at Mach number 6. Minimum operating pressures range from about one-tenth to one-twentieth of the maximum at each Mach number.

Tunnel B has a 50-in.-diam test section and two interchangeable axisymmetric contoured nozzles to provide Mach numbers of 6 and 8. The tunnel can be operated continuously over a range of pressure levels from 20 to 300 psia at Mach number 6, and 50 to 900 psia at Mach number 8, with air supplied by the VKF main compressor plant. Stagnation temperatures sufficient to avoid air liquefaction in the test section (up to 1350°R) are obtained through the use of a natural gas fired combustion heater. The entire tunnel (throat, nozzle, test section, and diffuser) is cooled by integral, external water jackets. Each tunnel is equipped with a model injection system which allows removal of the model from the test section while the tunnel remains in operation. A description of the tunnels may be found in the Test Facilities Handbook*.

2.2 TEST ARTICLES

Three space shuttle orbiter models were used to obtain the thin-skin thermocouple data for this test. Two of the test articles were 0.0175 scale models of the full orbiter and were designated as the 60-Ø and 56-Ø models. The third model was a 0.04 scale 50 percent forebody model of the orbiter and was identified as the 83-Ø model. All of the models were supplied by Rockwell International.

The 60-Ø model was a 0.0175 scale thin-skin thermocouple model of the Rockwell International Vehicle 5 configuration. The model was constructed of 17-4 PH stainless steel with a nominal skin thickness of 0.030 in. at the instrumented areas. All thermocouples were spot welded to the thin-skin inner surface.

A photograph of the 60-Ø model injected in the Tunnel B test section is shown in Fig. 3. The basic dimensions and coordinate definitions for the 0.0175 scale model are shown in the sketch presented in Fig. 4. The deflection angles of the speedbrake, body flap and elevons were varied during this test and recorded on the tabulated data.

The 56-Ø model was a 0.0175 scale phase change paint model with the same external contour as the 60-Ø model. The pilot side (left) of the fuselage has been replaced with a thin-skin thermocouple insert contoured to the vehicle lines. This insert was constructed of 17-4 PH stainless steel with a nominal skin thickness of 0.020 in. at the thermocouple locations. A photograph of the 56-Ø model injected in Tunnel A is shown in Fig. 5. The dimensions and coordinate system presented in Fig. 4 also apply to the 0.0175 scale 56-Ø model.

The 83-Ø model was a 0.04 scale model of the forward 50 percent of the orbiter. This model was also constructed of 17-4 PH stainless steel with a nominal skin thickness of 0.030 in. A photograph of the 83-Ø model injected in Tunnel B is shown in Fig. 6. The coordinate system and basic dimensions for the 83-Ø model are presented in Fig. 7.

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*Test Facilities Handbook (Eleventh Edition). "von Karman Gas Dynamics Facility, Vol. 3." Arnold Engineering Development Center, June 1979.

Each of the orbiter models was installed in more than one configuration to fulfill the test requirements of Mach number (Tunnel selection), angle of attack, and yaw. Both the 56-Ø and the 60-Ø models were tested as the orbiter alone and mated with the external tank and both solid rocket boosters designated as the ØTS configuration. Installation sketches of each of the ten configurations are presented in Fig. 8. The installations illustrated in Figs. 8c and 8d each represent two configurations by interchanging the 56-Ø and the 60-Ø models. Each installation was identified with a configuration code that is listed on the tabulated data. These configuration codes are also listed in Table 1, Appendix II.

2.3 TEST INSTRUMENTATION

2.3.1 Test Conditions

Tunnel A stilling chamber pressure is measured with a 15-, 60-, 150-, or a 300-psid transducer referenced to a near vacuum. Based on periodic comparisons with secondary standards, the accuracy (a bandwidth which includes 95 percent of the residuals, i.e. 2σ deviation) of these transducers is estimated to be within ±0.2 percent of pressure or ±0.015 psi, whichever is greater. Stilling chamber temperature is measured with a copper-constantan thermocouple with an accuracy of ±3°F.

Tunnel B stilling chamber pressure is measured with a 200- or 1000-psid transducer referenced to a near vacuum. Based on periodic comparisons with secondary standards, the accuracy of the transducers is estimated to be within ±0.25 percent of pressure or ±0.3 psi, whichever is greater for the 200-psid range and ±0.25 percent of pressure or ±0.8 psi, whichever is greater for the 1000-psid range. Stilling chamber temperature measurements are made with Chromel®-Alumel® thermocouples which have an uncertainty of ±(1.5F + 0.375 percent of reading in °F).

2.3.2 Test Data

The 60-Ø model instrumentation consisted of 600 thirty gauge iron-constantan and chromel-constantan thermocouples. Thermocouple locations for this model are illustrated in Fig. 9; the dimensional locations and skin thickness are listed in Table 2. The thermocouples identified by a number only are iron-constantan. The thermocouples identified by a number followed by the letter A or C are chromel-constantan. The letter A designates a new thermocouple location added specifically for this test. The letter C designates the location of a previously existing thermocouple which has been repaired with chromel-constantan wire.

The 56-Ø model instrumentation consisted of 80 thirty gauge chromel-constantan thermocouples located on the thin-skin insert. The thermocouple locations for this model are illustrated in Fig. 10. The dimensional locations and skin thicknesses are listed in Table 3.

The 83-Ø model was instrumented with 482 thirty gauge chromel-constantan thermocouples as illustrated in Fig. 11. The dimensional locations and skin thicknesses for the thermocouples on this model are included in Table 4.

Data from a maximum of 98 thermocouples can be recorded during each tunnel injection. Seventeen sets of thermocouples were required to accommodate the large number of thermocouples on this test. These sets are called Constant Sets in the tabulated data. A listing of the seventeen Constant Sets is given in Table 5. This listing includes all of the thermocouples that were installed for the test. Some of the listed thermocouples were determined to be inoperative and these have been deleted from the tabulated data. A total of three Constant Sets could be connected at one time. A three position selector switch was used to select the desired Constant Set for each injection. The specific Constant Sets that were connected for each model configuration are listed in Table 1.

3.0 TEST DESCRIPTION

3.1 TEST CONDITIONS

The test was conducted at a nominal Mach number of 8 in Tunnel B and nominal Mach numbers of 3 and 4 in Tunnel A. A summary of the specific test conditions is given below.

MACH NO.	PO, psia	TO, °R	Q-INF, psia	P-INF, psia	RE/FT x 10^{-6}
3.01	10	710	1.7	0.27	1.0
3.01	34		5.8	0.91	3.5
3.01	37		6.3	0.99	3.8
4.01	17		1.2	0.11	1.0
4.02	33		2.4	0.21	2.0
4.02	58		4.2	0.37	3.5
4.02	66	710	4.8	0.42	4.0
7.9	100	1250	0.5	0.01	0.5
7.94	205	1260	1.0	0.02	1.0
7.98	435	1300	2.0	0.05	2.0
7.99	670	1320	3.1	0.07	3.0
8.0	850	1350	3.9	0.09	3.7

A more detailed test summary showing all configurations tested and the variables for each is presented in Table 6.

3.2 TEST PROCEDURE

In the VKF continuous flow wind tunnels (A, B, C), the model is mounted on a sting support mechanism in an installation tank directly underneath the tunnel test section. The tank is separated from the tunnel by a pair of fairing doors and a safety door. When closed, the fairing doors, except for a slot for the pitch sector, cover the opening to the tank and the safety door seals the tunnel from the tank area.

After the model is prepared for a data run, the personnel access door to the installation tank is closed, the tank is vented to the tunnel flow, the safety and fairing doors are opened, and the model is injected into the airstream, and the fairing doors are closed. After the data are obtained, the model is retracted into the tank and the sequence is reversed with the tank being vented to atmosphere to allow access to the model in preparation for the next run ,if necessary. The sequence is repeated for each configuration change.

The initial step prior to recording the test data was to cool the model uniformly to approximately 80°F with high pressure air. Once the cooling cycle was complete, the desired model attitude was established in the tank prior to injection. With the desired tunnel free stream conditions established, the model was then injected into the tunnel. At lift-off, the initial temperature, TW_i, for each thermocouple on the selected Constant Set was recorded. In Tunnel A, the data acquisition sequence was started prior to the model reaching the airstream. When the model reached tunnel centerline, it was translated to the forward test section to clear an area of tank induced shock impingement. The data acquisition sequence continued until the model reached the full forward position. In Tunnel B, the model was injected directly into the test section. Therefore, the data acquisition sequence was initiated at lift-off and continued for approximately 3 seconds after the model reached the tunnel centerline. After each injection the model was retracted and the cycle was repeated to cool the model to an isothermal state.

A Beckman® 210 analog-to-digital converter was used in conjunction with a Digital Equipment Corp.® (DEC) PDP-11 computer and a DEC-10 computer to record the temperature data. The Beckman® converter sampled the output of each thermocouple approximately 15 times per second.

3.3 DATA REDUCTION

The reduction of thin-skin thermocouple data normally involves only the calorimetric heat balance, which, in coefficient form is

$$H(TO) = wbc_p \frac{DTWDT}{TO-TW} \tag{1}$$

Radiation and conduction losses are neglected in this heat balance, and data reduction simply requires evaluation of DTWDT from the temperature-time data and determination of model material properties. For the present tests, radiation effects were negligible; however, conduction effects were potentially significant in several regions of the model. To permit identification of these regions and improve evaluation of the data, the following procedure was used.

Separation of variables and integration of Eq. (1), assuming constant w, b, c_p and TO yields

$$\frac{H(TO)}{wbc_p} \quad (t - t_i) = \ell n \left[\frac{TO-TW_i}{TO-TW} \right] \tag{2}$$

Since $H(TO)/wbc_p$ is a constant, plotting $\ell n\ (TO-TW_i)/(TO-TW_i)$ versus time will give a straight line if conduction is negligible. Thus, deviations from a straight line can be interpreted as conduction effects.

The data were evaluated in this manner and, generally, a reasonably linear portion of the curve could be found for all thermocouples. A linear least-squares curve fit of $\ell n\left[(TO-TW_i)/(TO-TW)\right]$ versus time was applied to the data. In Tunnel A the data reduction time was delayed for all thermocouples that were influenced by the tank induced shock until they had cleared this region. The data reduction time for Tunnel B is typically started at centerline. However, the data for groups 5-239 were reduced starting 0.4 seconds after centerline to obtain a linear portion of the curve. The curve fit extended for a time span which was a function of the heating rate, as shown on the following list.

Range	Number of Points	Time Span, sec
DTWDT > 32	5	0.27
16 < DTWDT ≤ 32	7	0.41
8 < DTWDT ≤ 16	9	0.54
4 < DTWDT ≤ 8	13	0.82
2 < DTWDT ≤ 4	17	1.09
1 < DTWDT ≤ 2	25	1.63
DTWDT ≤ 1	41	2.72

In general, the time spans given above were adequate to keep the evaluation of the right-hand side of Eq. (2) within the linear region. The value of c_p is not constant, as assumed, and the relation

$$c_p = 0.0797 + (5.556 \times 10^{-5})\ TW, \text{ (17-4 PH stainless steel)} \tag{3}$$

was used with the computed value of TW at the midpoint of the curve fit. The maximum variation of c_p over any curve fit was less than 1.5 percent. Thus, the assumption of constant c_p was reasonable. The value of density used for the 17-4 PH stainless steel skin was, w = 490 lbm/ft^3, and the skin thickness, b, for each thermocouple is listed in Tables 2, 3, or 4. The four thermocouples (T/C No. 428, 429, 430, and 431) on the base of the 60-Ø model, see Fig. 9i, were attached to 15-5 PH stainless steel. The value of density for the 15-5 PH stainless steel was 490 lbm/ft^3 and the value of c_p was

$$c_p = 0.0645 + (5.8 \times 10^{-5})\ TW, \text{ Btu/lbm °R} \tag{4}$$

The heat-transfer coefficient calculated from Eq. 2 was normalized using the Fay-Riddell stagnation point coefficient, HREF, based on a nose radius of 1.0 ft full scale (see Appendix III).

In addition to computing heat-transfer coefficient using TO as the assumed adiabatic wall temperature, TAW, coefficients were computed using an assumed TAW of 0.95 TO and a computed value of RTO for the data in Tunnel A, and 0.9 TO and RTO for the data in Tunnel B. The value of R is defined so as to equal TAW/TO. The value of R was computed by the following equation supplied by Rockwell International.

$$R = a_1 + (a_2)(\sin(\alpha + \varepsilon))^{a_3} \tag{5}$$

where α is the model angle of attack and ε is the local model surface deflection angle at a selected thermocouple location. The values of a_1, a_2, and a_3 for each Mach number are:

MACH NO.	a_1	a_2	a_3
3.0	0.9345	0.1004	2.165
4.0	0.922	0.1004	1.965
8.0	0.867	0.133	1.55

The local model surface angles, ε, for the appropriate thermocouples used in this test on the 60-Ø model are presented in Table 7. The local surface angles on the 83-Ø model are presented in Table 8. For those thermocouples where ε was not given, an R value of 0.95 was used for Mach numbers 3 and 4 and a value of 0.9 was used for Mach 8.

The method used to calculate the analytical temperature ratio, R, has been applied to all the tabulated data. However, in regions of separated flow or complex interaction, the basic assumptions no longer apply and the computed values of R should be used with care.

The use of three assumed values of TAW provides an indication of the sensitivity of the heat-transfer coefficients to the value of TAW assumed. As can be noted in the tabulated data, there are large percentage differences in the values of the heat-transfer coefficients calculated from the three assumed values of TAW. Therefore, if the data are to be used for flight predictions, the value selected for TAW/TO is obviously very important.

3.4 DATA UNCERTAINTY

An evaluation of the influence of random measurement errors is presented in this section to provide a partial measure of the uncertainty of the final test results presented in this report. Although evaluation of the systematic measurement error (bias) is not included, it should be noted that the instrumentation accuracy values (given in Section 2.3) used in this evaluation represent a total uncertainty combination of both systematic and two-sigma random error contributions.

3.4.1 Test Conditions

Accuracy of the basic tunnel parameters PO and TO (see Section 2.3) and the two-sigma deviation in Mach number determined from test section flow calibrations were used to estimate uncertainties in the other free-stream properties, using the Taylor series method of error propagation; i.e.,

$$(\Delta F)^2 = \left(\frac{\partial F}{\partial X_1}\,\Delta X_1\right)^2 + \left(\frac{\partial F}{\partial X_2}\,\Delta X_2\right)^2 + \left(\frac{\partial F}{\partial X_3}\,\Delta X_3\right)^2 + \ldots \left(\frac{\partial F}{\partial X_n}\,\Delta X_n\right)^2 \quad (6)$$

where ΔF is the absolute uncertainty in the dependent parameter $F = f(X_1, X_2, X_3 \ldots X_n)$; $X_1, X_2, X_3 \ldots X_n$ are the independent measurements; and $\Delta X_1, \Delta X_2, \Delta X_3 \ldots \Delta X_n$ are the errors in the independent measurements.

	Uncertainty (±), percent					
MACH NO.	MACH NO.	PO	TO	P-INF	Q-INF	RE/FT
3.01	0.6	0.2	0.5	2.6	1.4	1.2
4.01	0.4	0.2	0.5	2.4	1.5	1.2
4.02	0.4	0.2	0.5	2.4	1.5	1.2
7.90	0.4	0.27	0.4	2.5	1.7	1.2
7.94	0.4	0.25	0.4	2.5	1.7	1.2
7.98	0.3	0.25	0.4	1.6	1.2	0.9
7.99	0.3	0.25	0.4	1.6	1.2	0.9
8.00	0.3	0.25	0.4	1.6	1.2	0.9

3.4.2 Reduced Data

Estimated uncertainties for the individual terms in Eq. (2) were used in the Taylor series method of error propagation to obtain uncertainty values of heat-transfer coefficient as represented typically by the ranges listed below:

	Uncertainty (±), percent	
Range of H(TO)	Tunnel A	Tunnel B
10^{-4}	15	10
10^{-3}	13	7
10^{-2}	10	5

These values assume that the uncertainty for the density, skin thickness, and specific heat of the thin skin material, as supplied by the user, are within ±1, ±3, and ±5 percent, respectively.

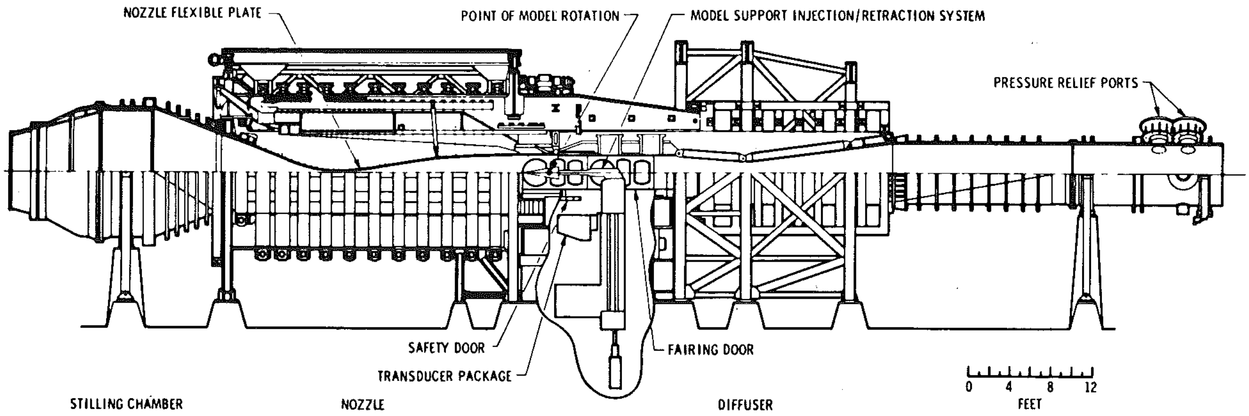
4.0 DATA PACKAGE PRESENTATION

Heat-transfer coefficients were obtained at selected locations on the 56-Ø, 60-Ø, and 83-Ø models of the space shuttle orbiter. Sample tabulated and plotted data are presented in Appendix IV. The final tabulated and plotted data were transmitted with this report to NASA-JSC and Rockwell International.

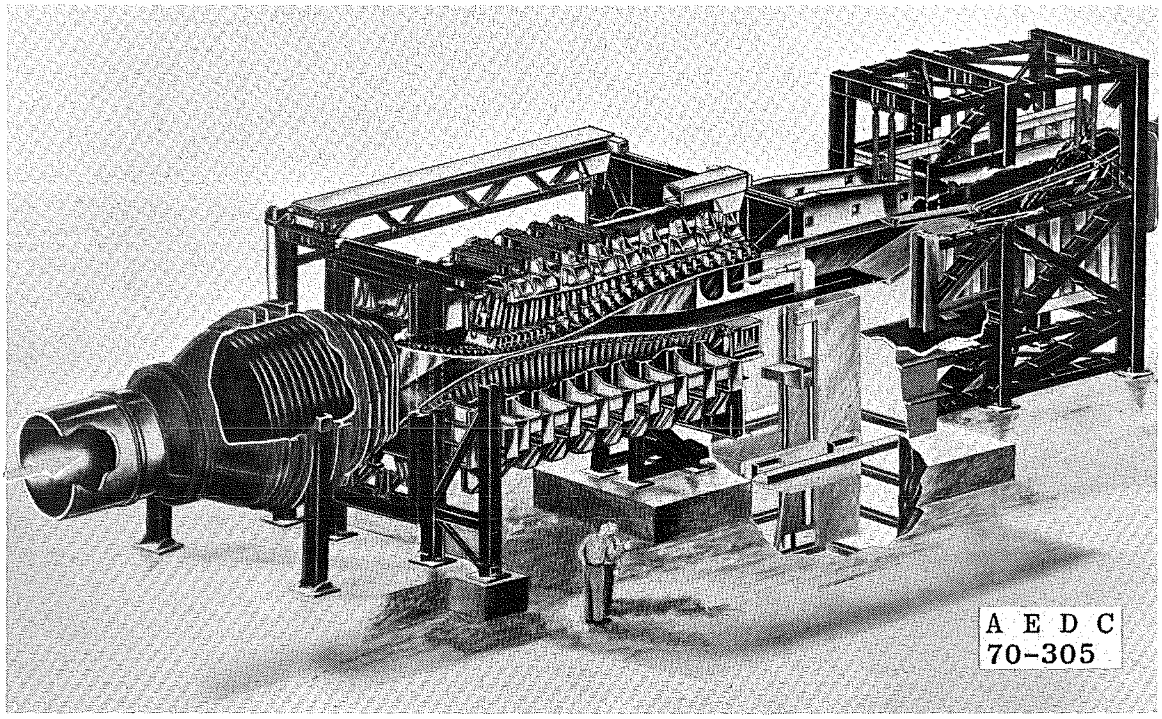
Representative data from the bottom centerline of the 60-Ø model are presented for Mach number 8 in Fig. 12. Also shown are data obtained from a previous test using the same model, and the comparison indicates the consistency of the test results.

APPENDIX I

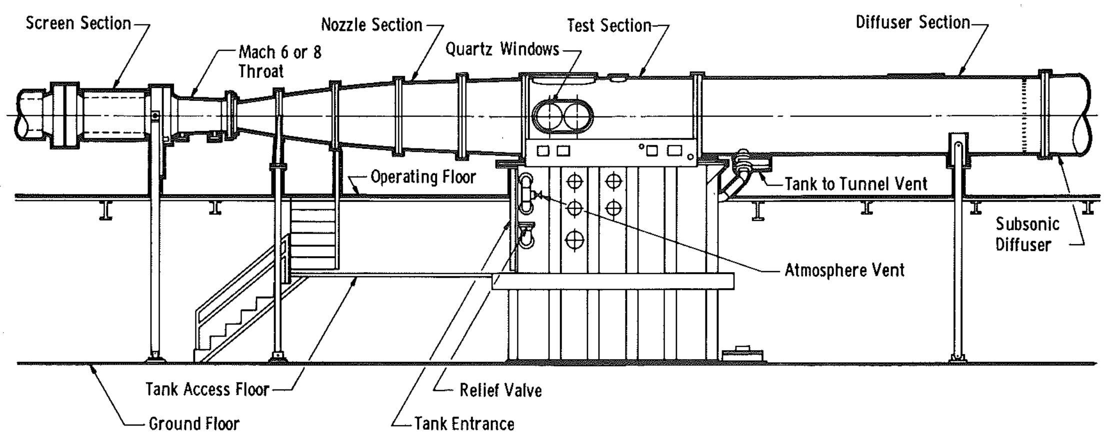
ILLUSTRATIONS



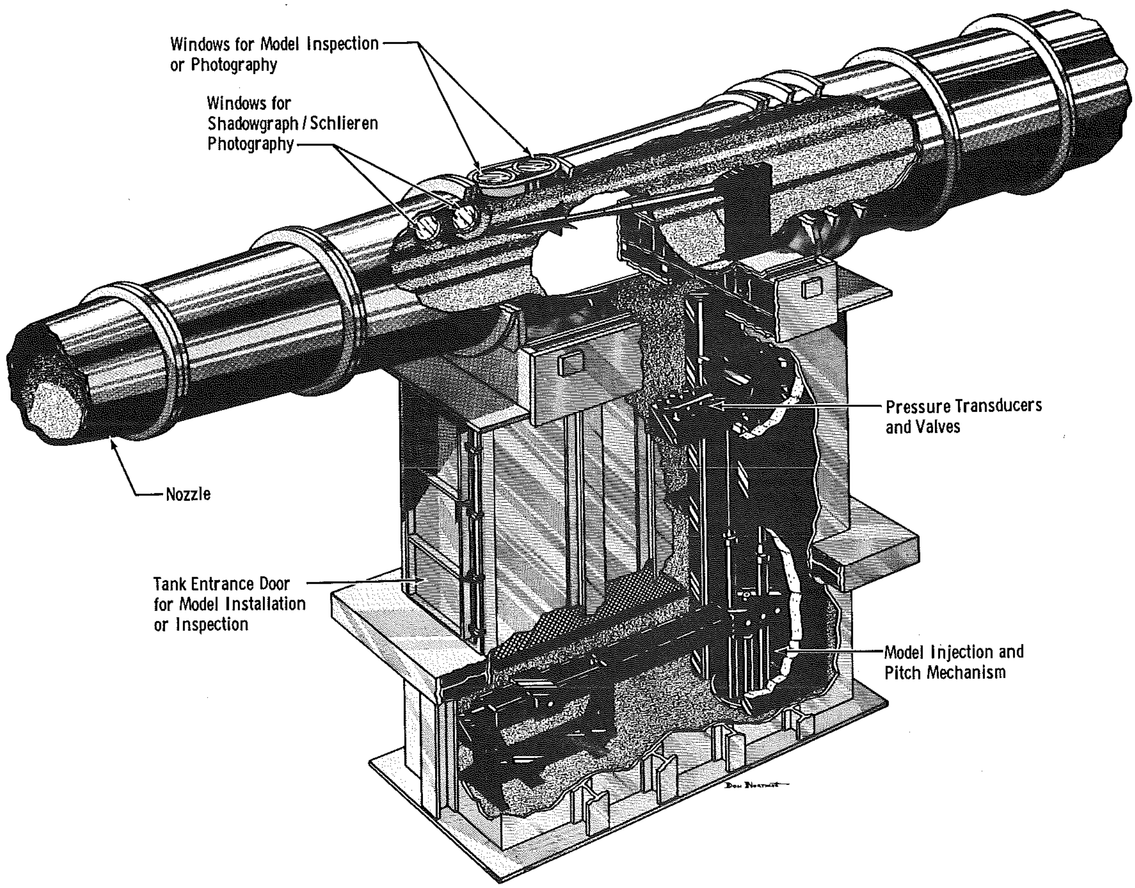
a. Tunnel assembly



b. Tunnel test section
Fig. 1 Tunnel A



a. Tunnel assembly



b. Tunnel test section
Fig. 1. Tunnel B

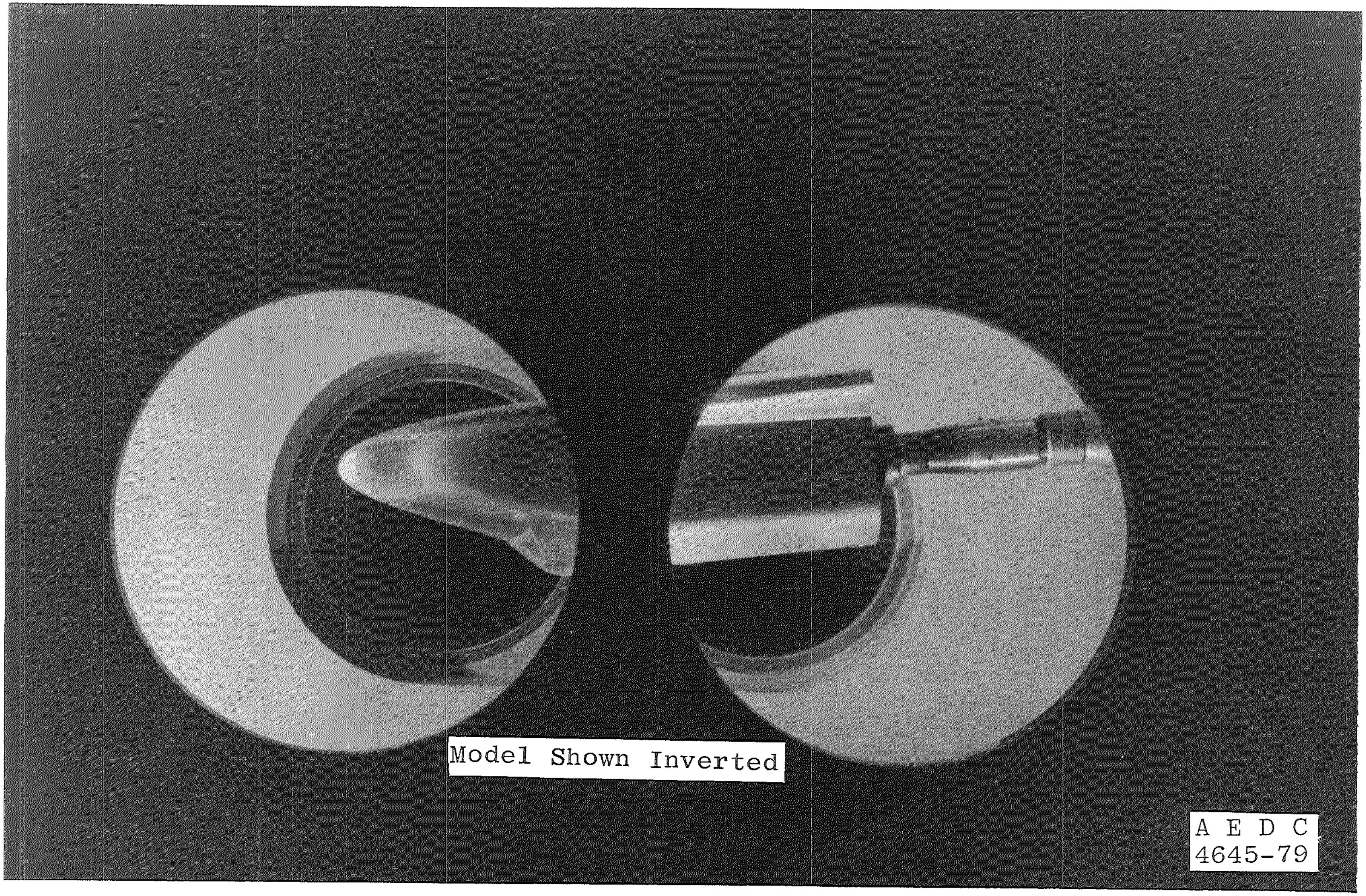


Figure 3. Installation Photograph of 60-ϕ Model

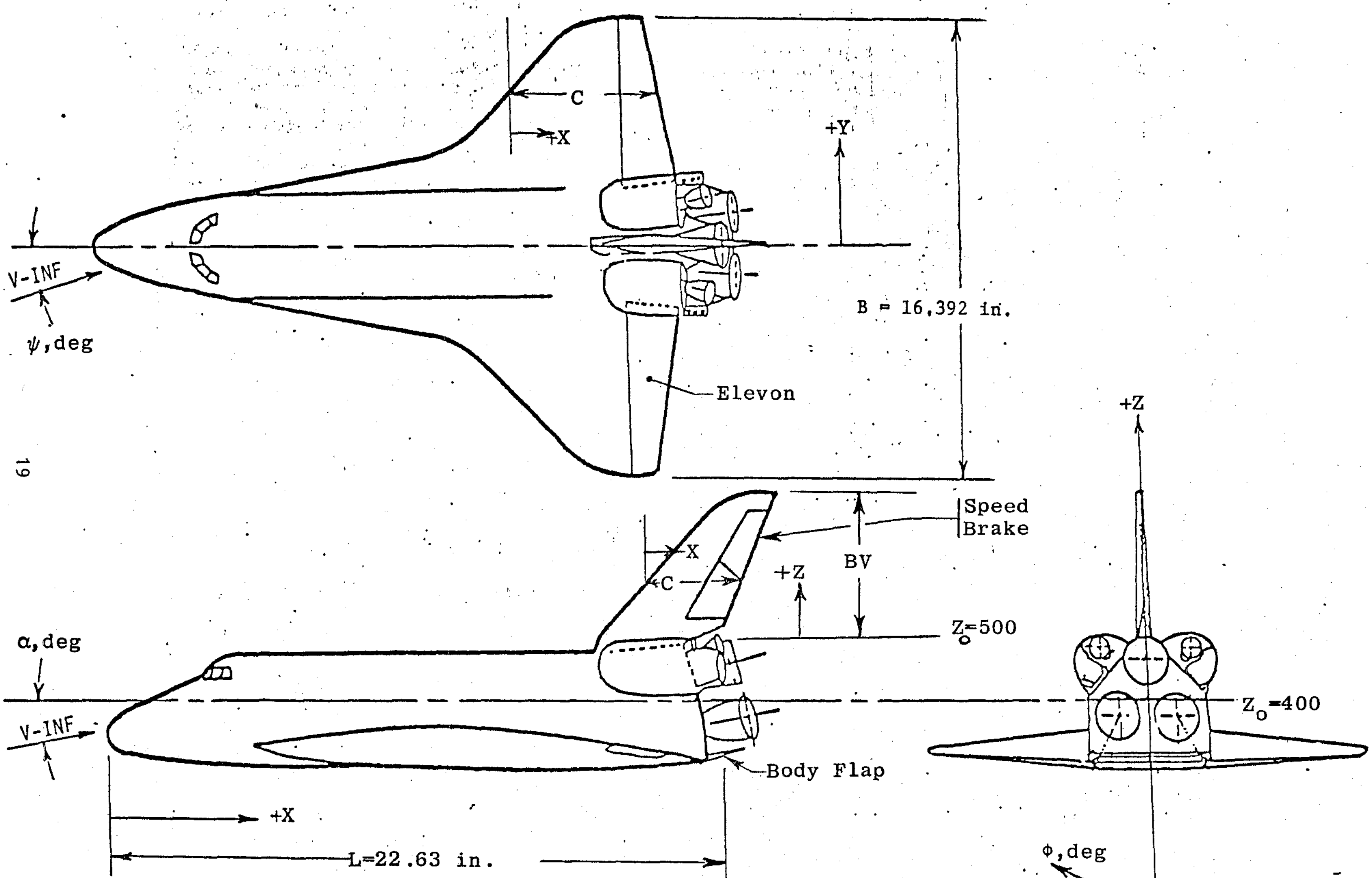


Fig. 4 Sketch of the Space Shuttle Orbiter Model

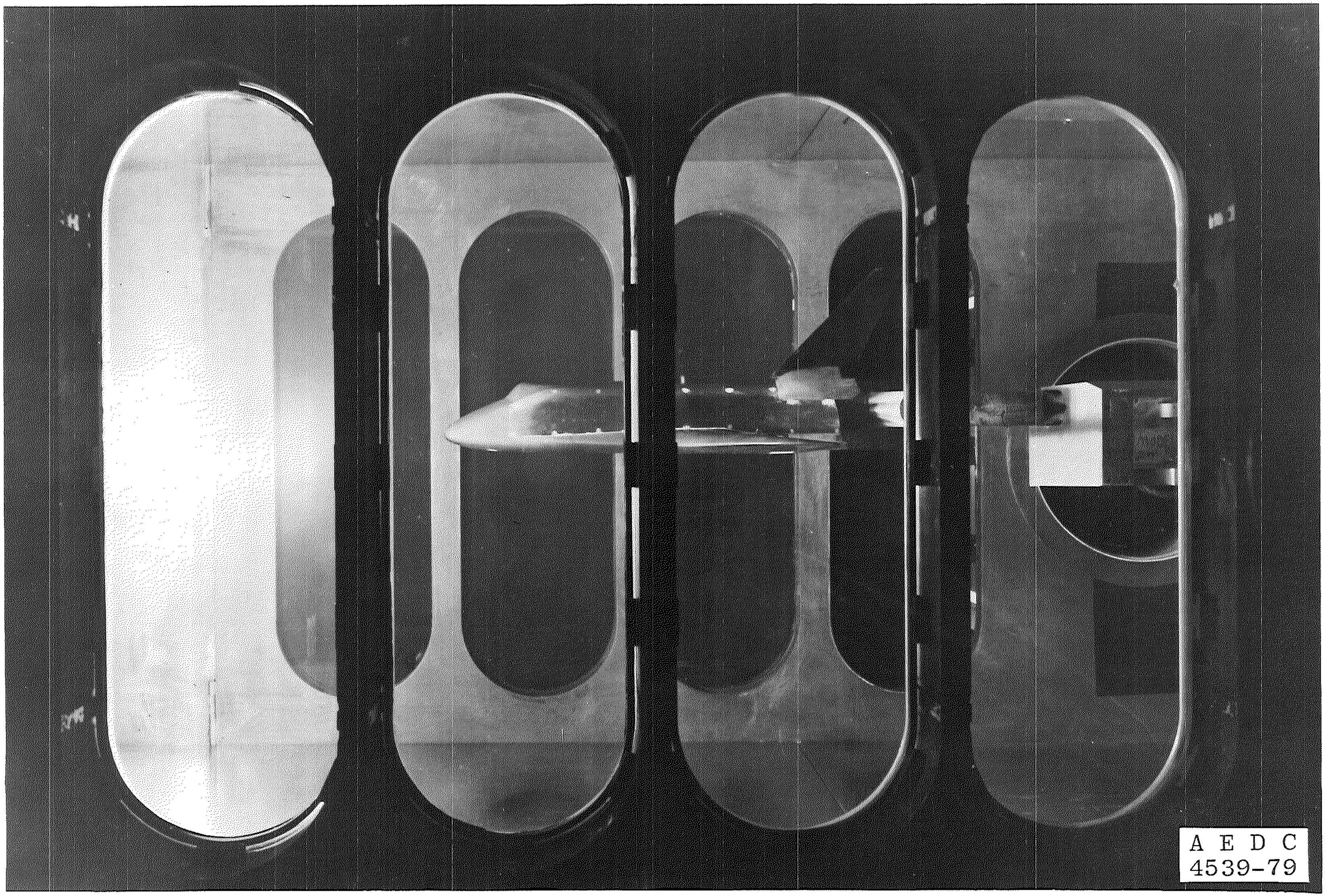


Figure 6. Installation Photograph of 83-ϕ Model

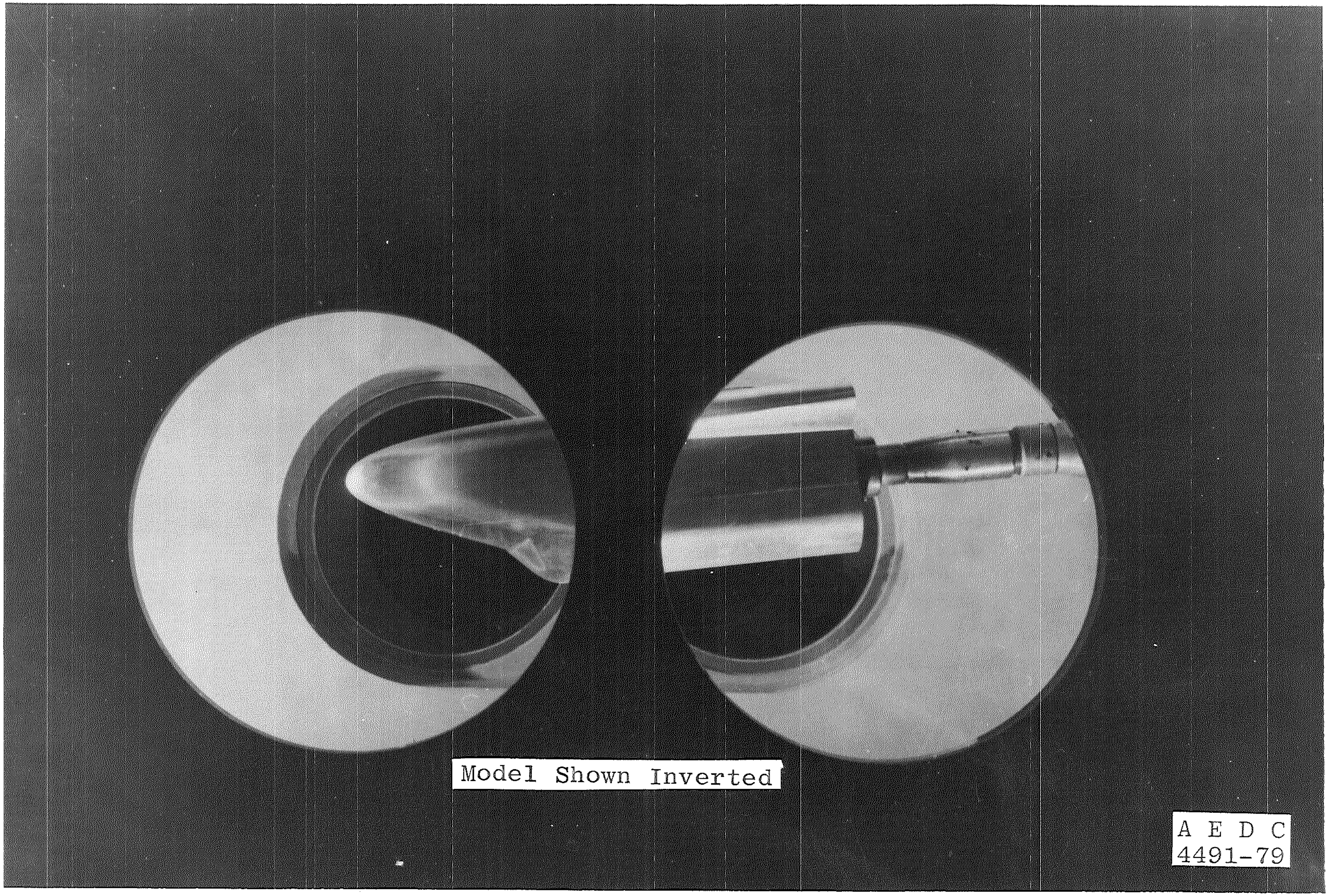


Figure 5. Installation Photograph of 56-ϕ Model

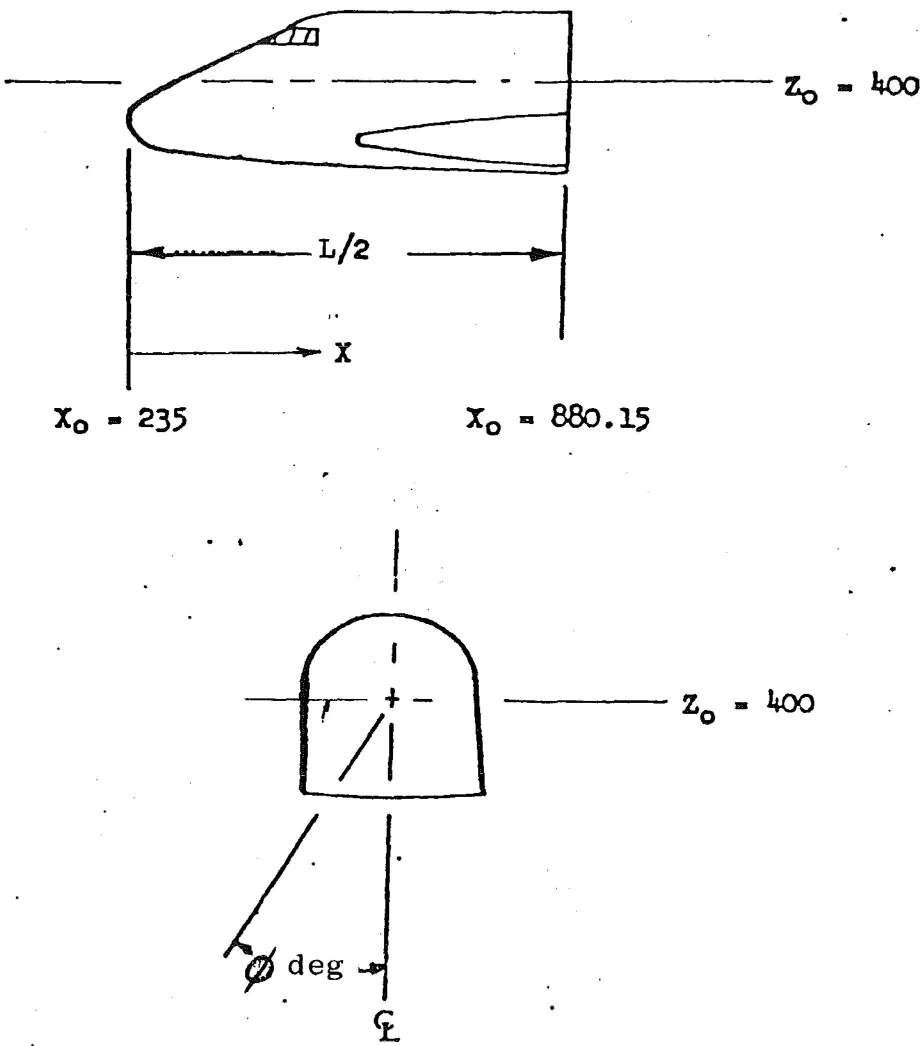
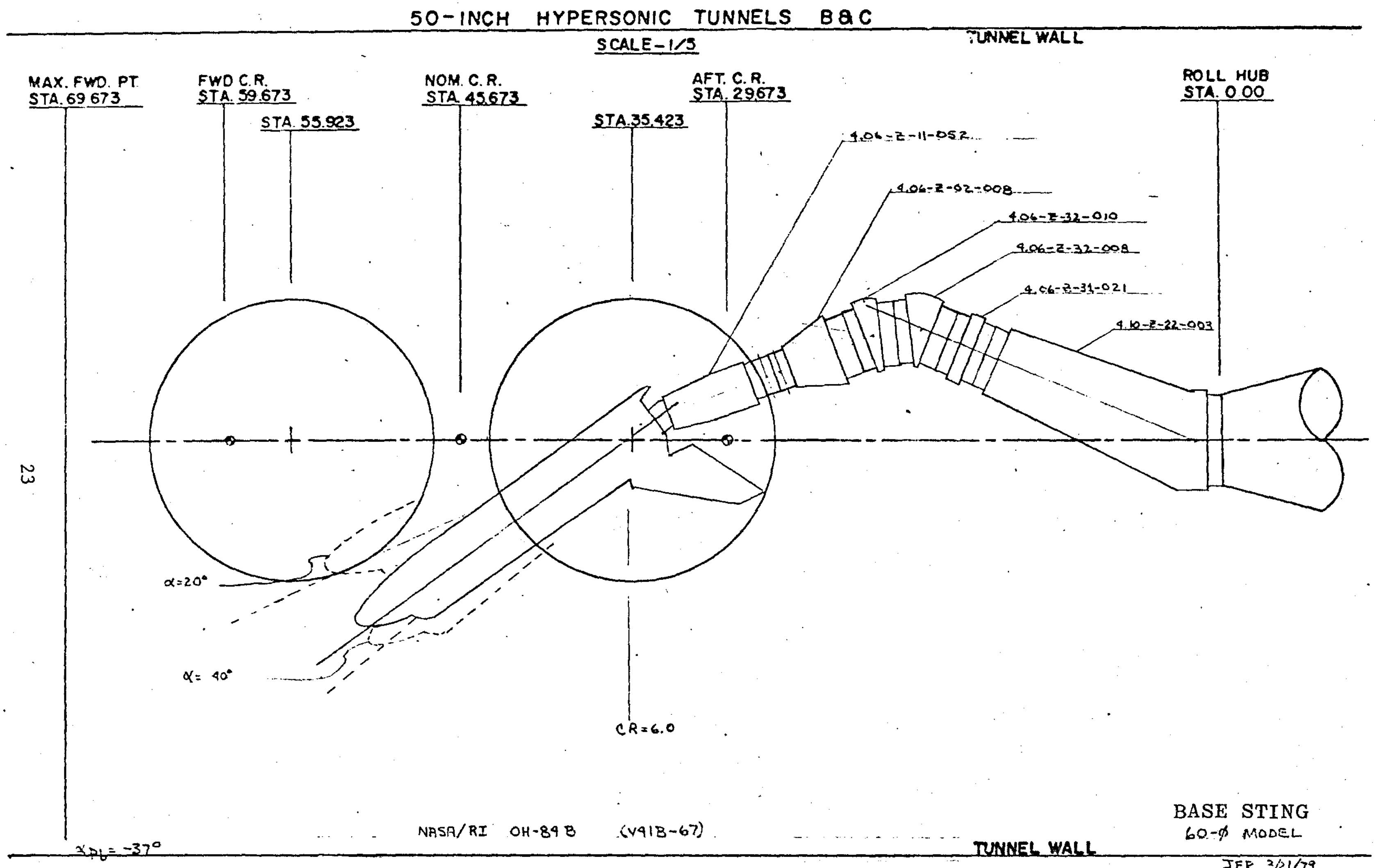
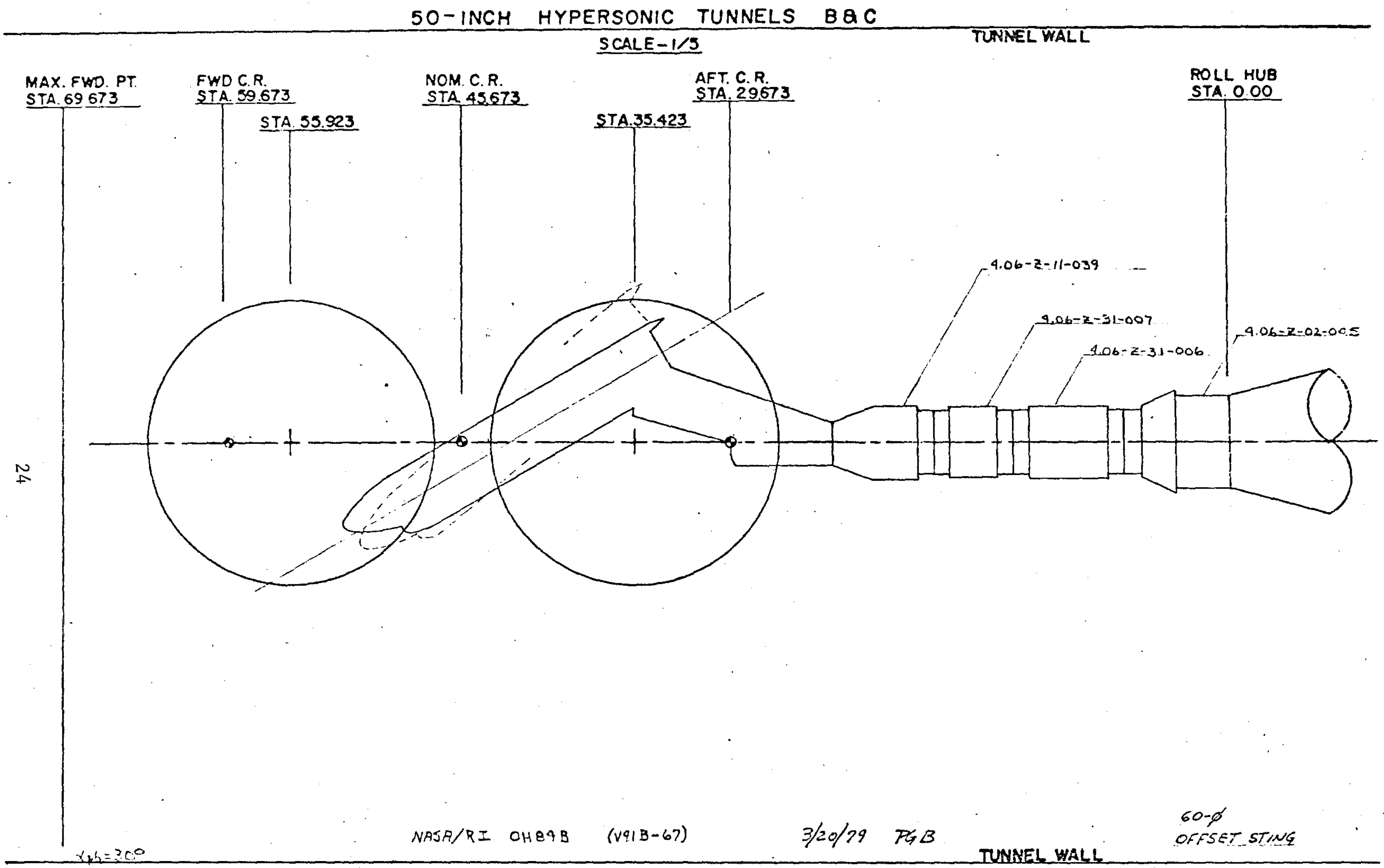


Fig. 7 Sketch of 83-Ø Model Coordinate System



a. Configuration Code 10

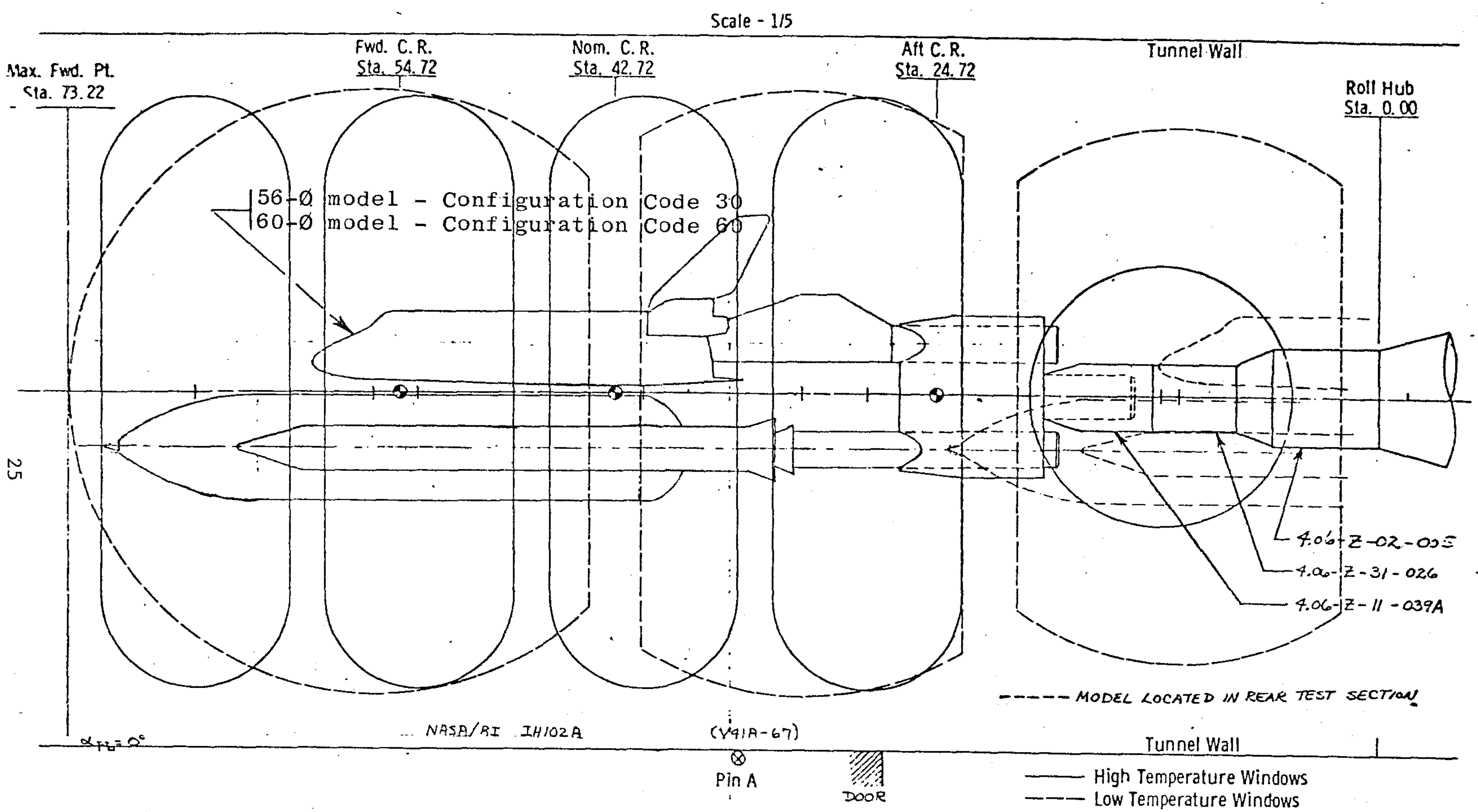
Fig. 8 Installation Sketches of Model Configurations



b. Configuration Code 20

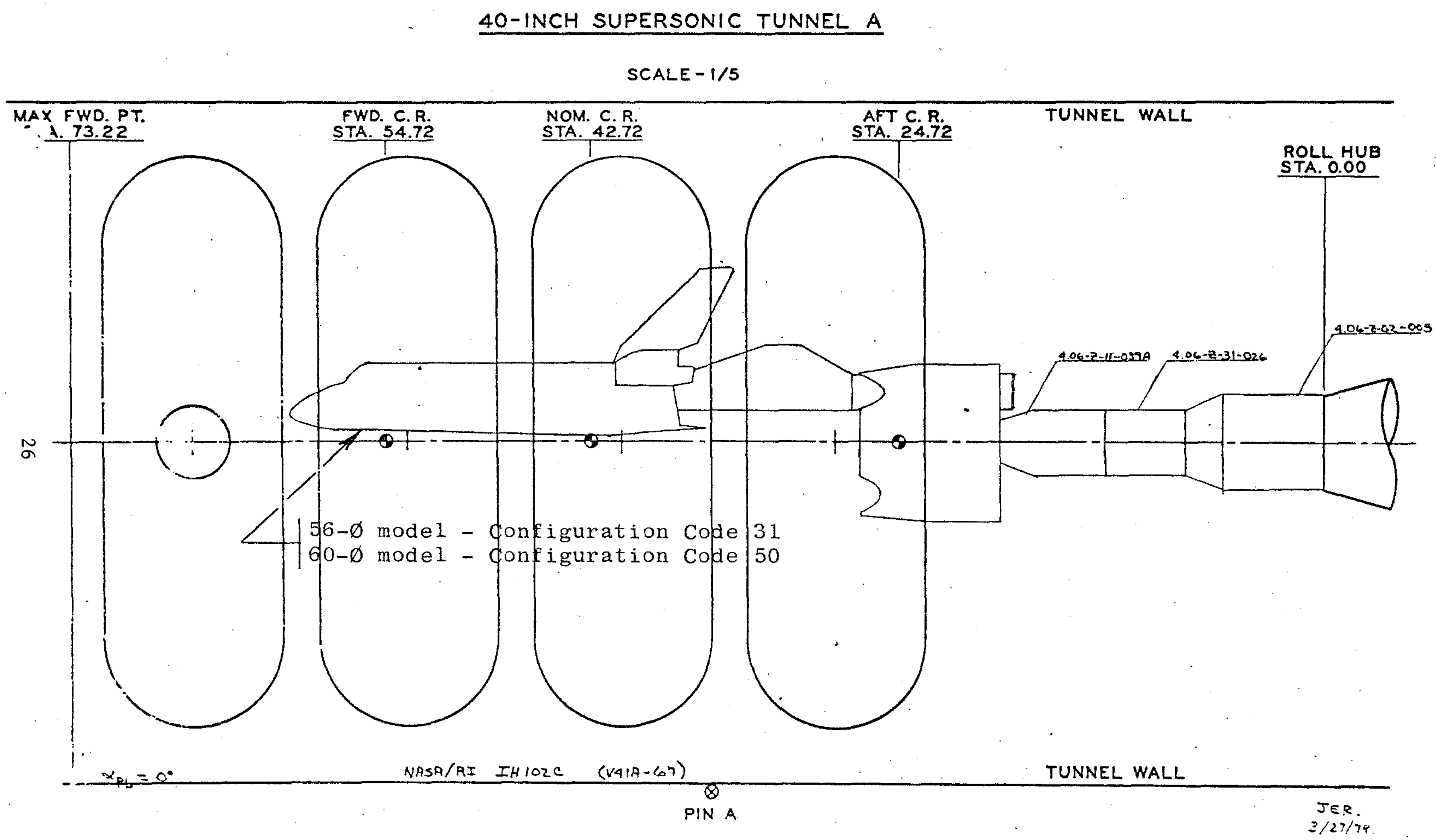
Fig. 8 Continued

40-INCH SUPERSONIC TUNNEL A



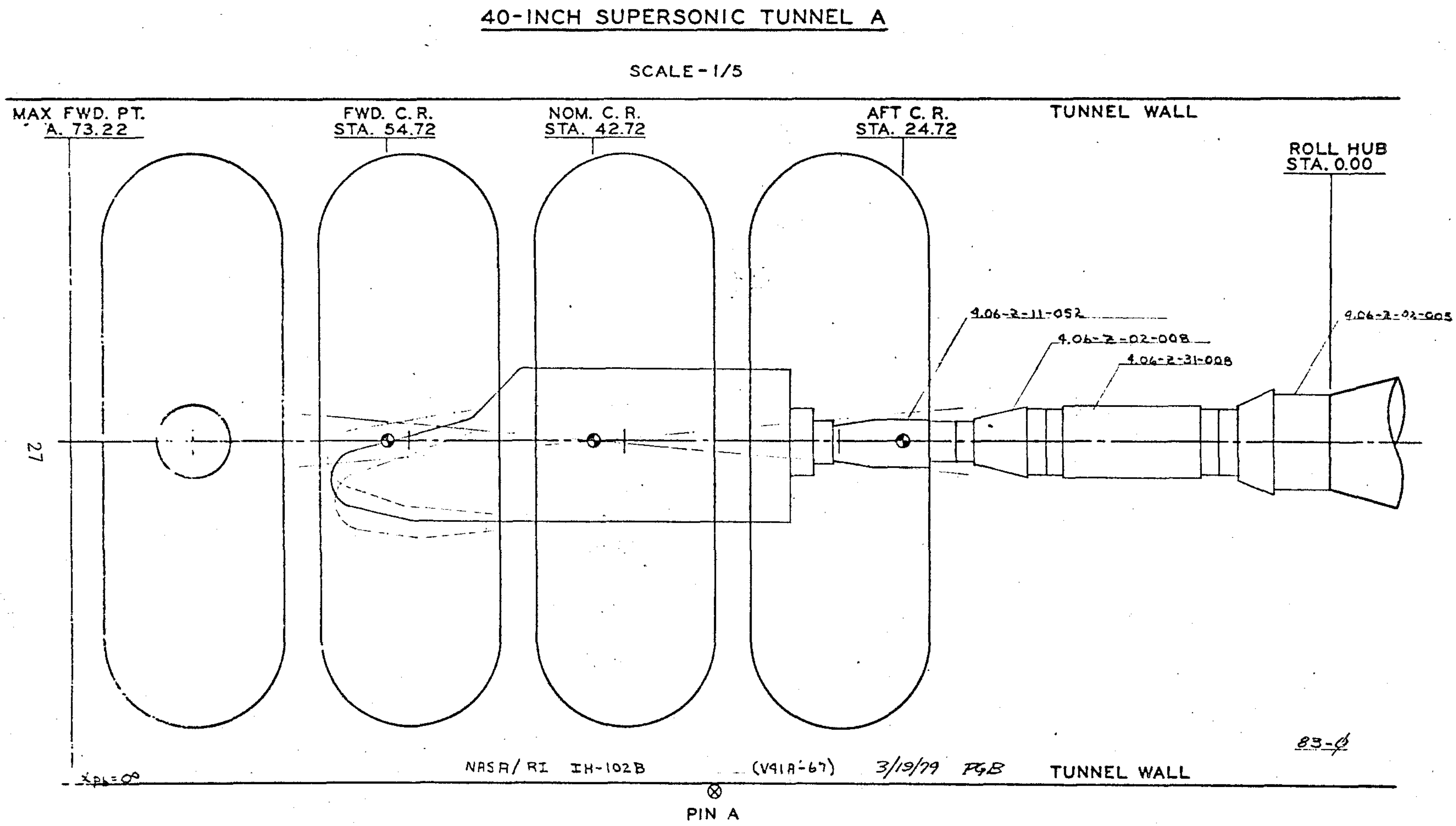
c. Configuration Codes 30 and 60

Fig. 8 Continued



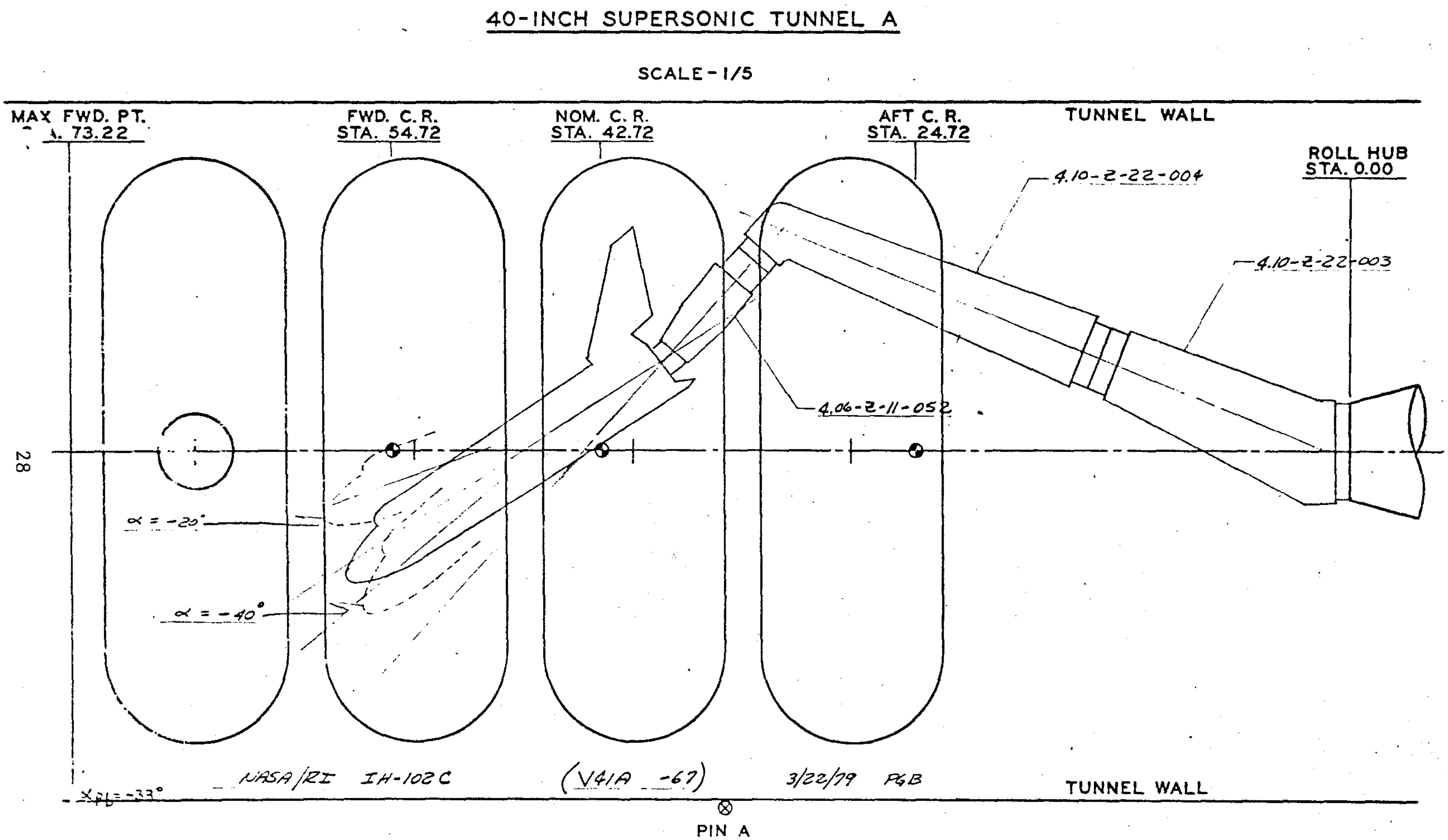
d. Configuration Codes 31 and 50

Fig. 8 Continued



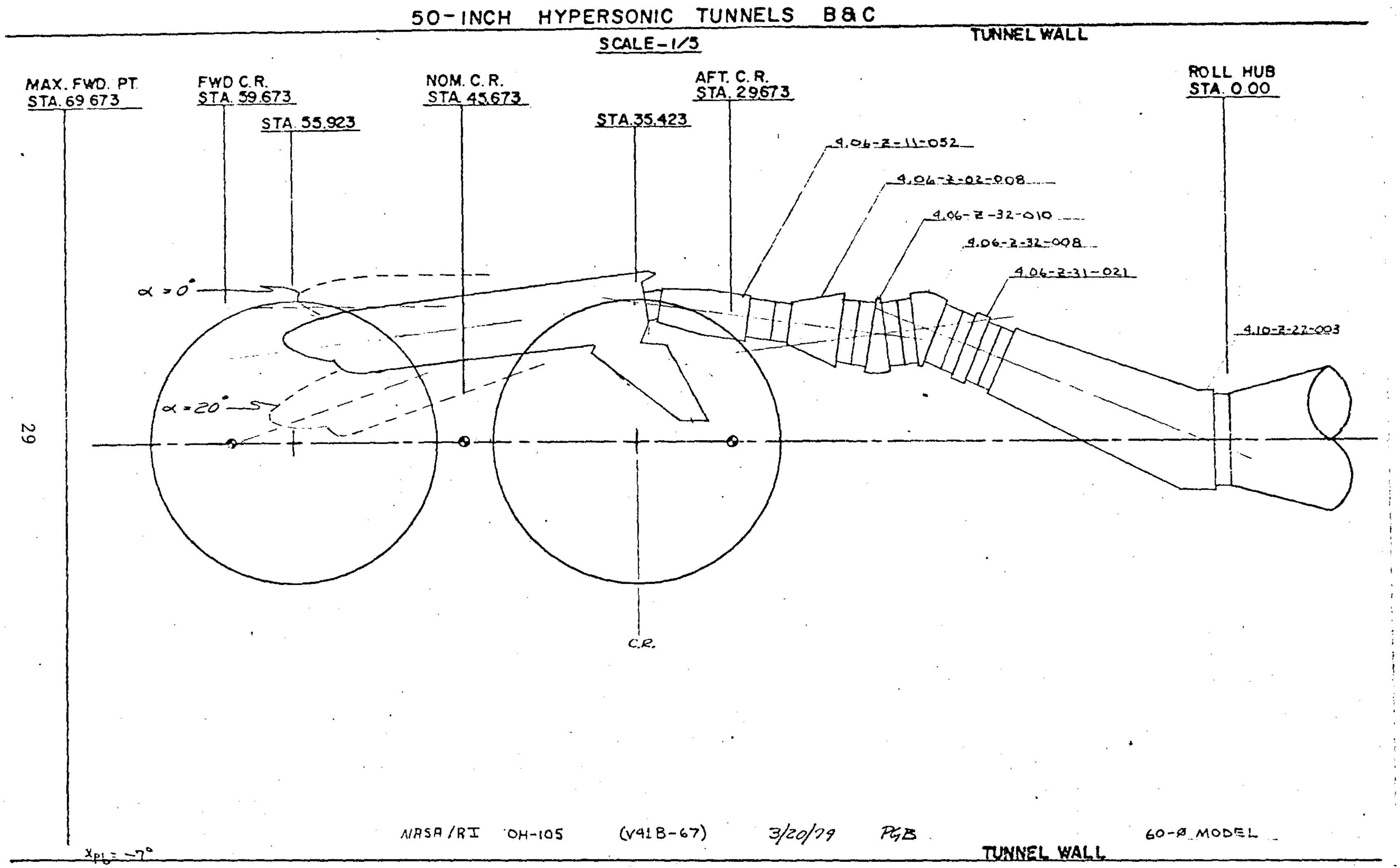
e. Configuration Code 40

Fig. 8 Continued



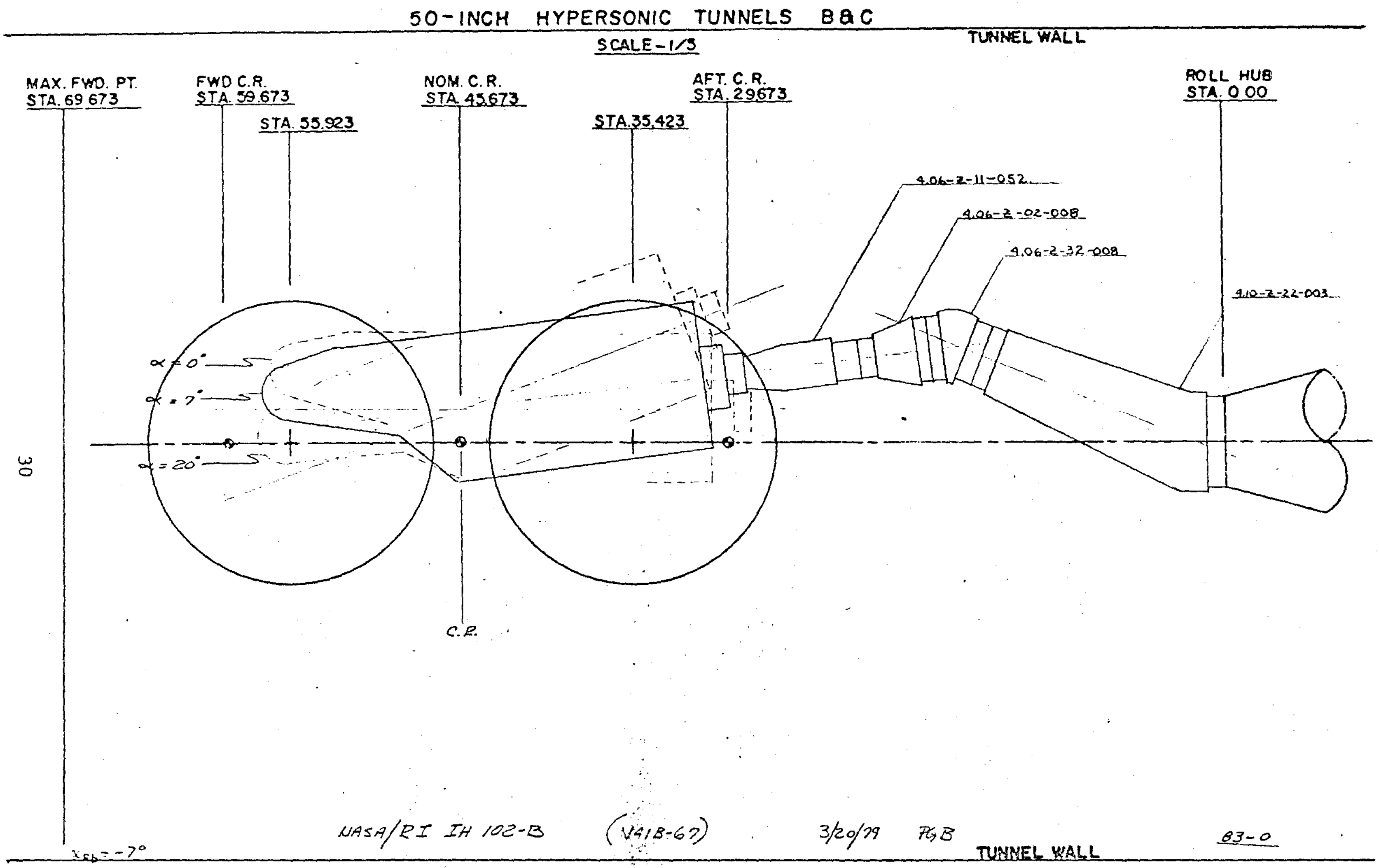
f. Configuration Code 51

Fig. 8 Continued



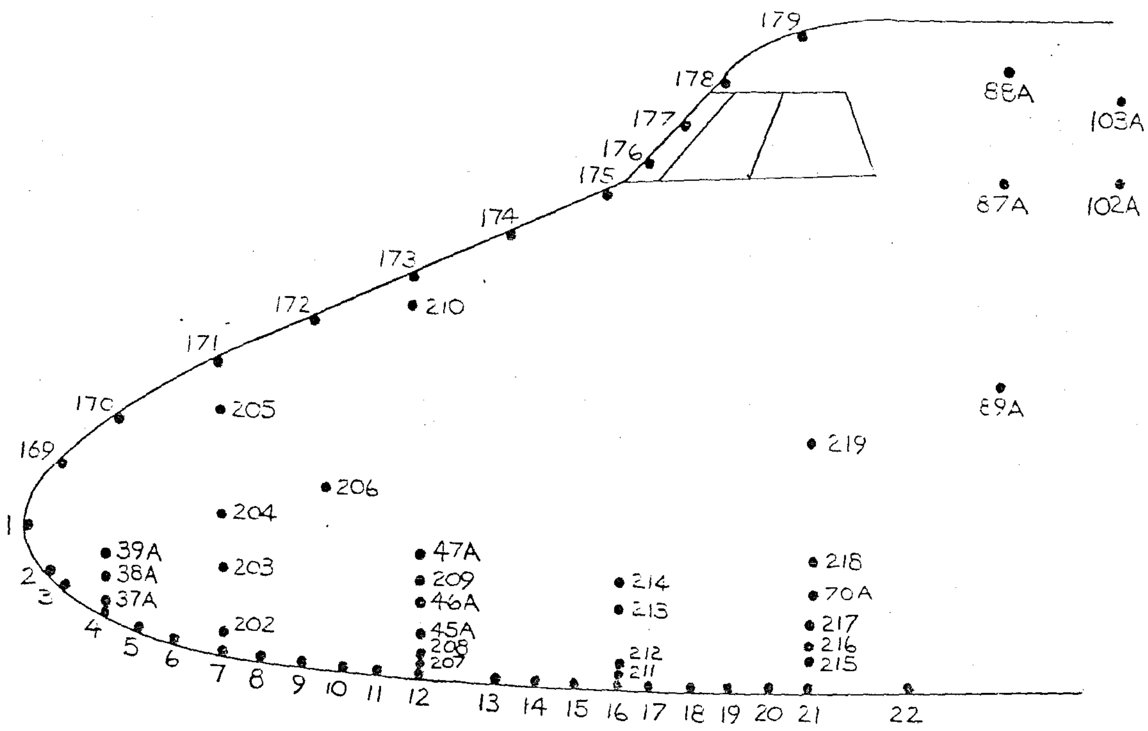
g. Configuration Code 70

Fig. 8 Continued



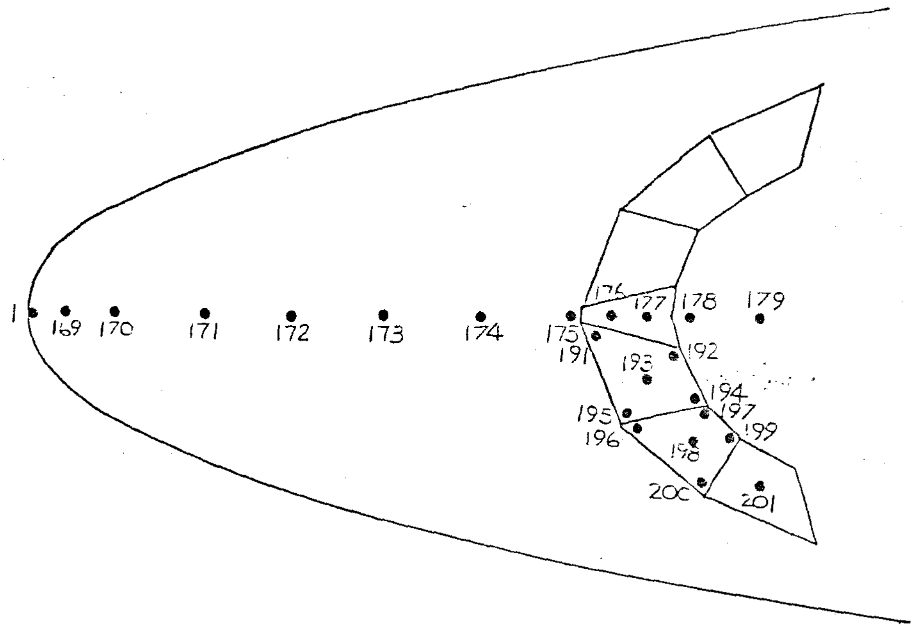
h. Configuration Code 80

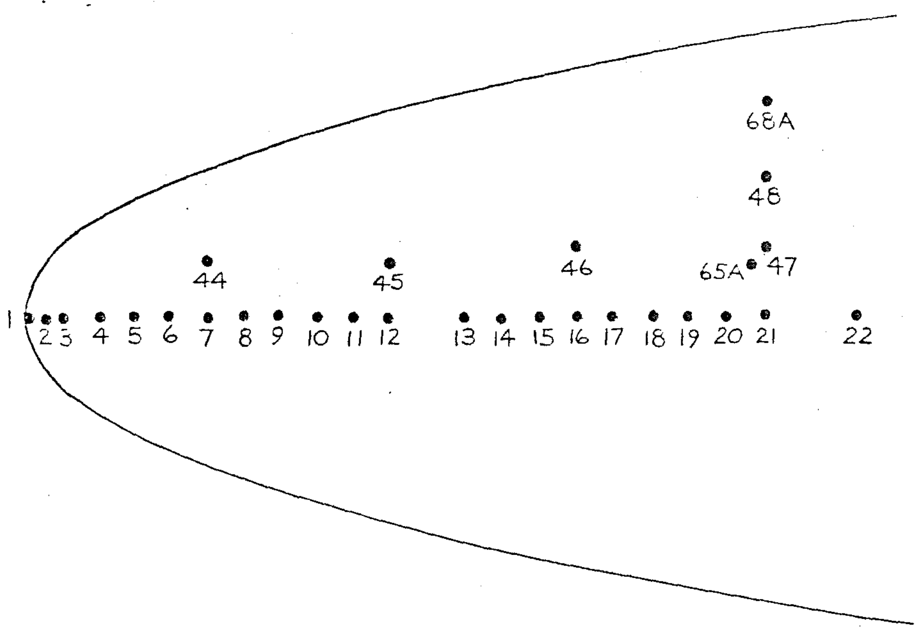
Fig. 8 Concluded



a. Nose and Canopy

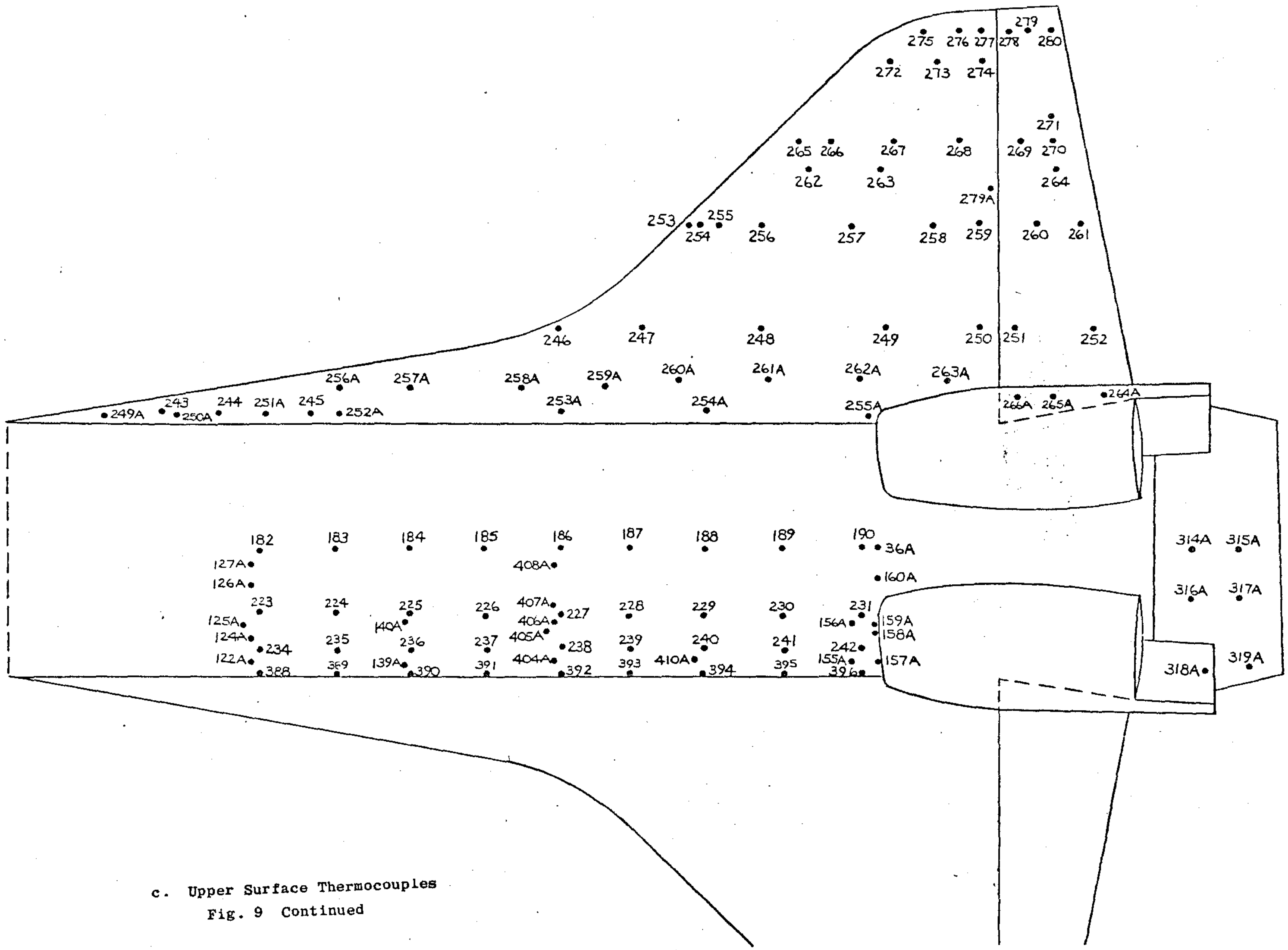
Fig. 9 Thermocouple Locations on 60-Ø Model





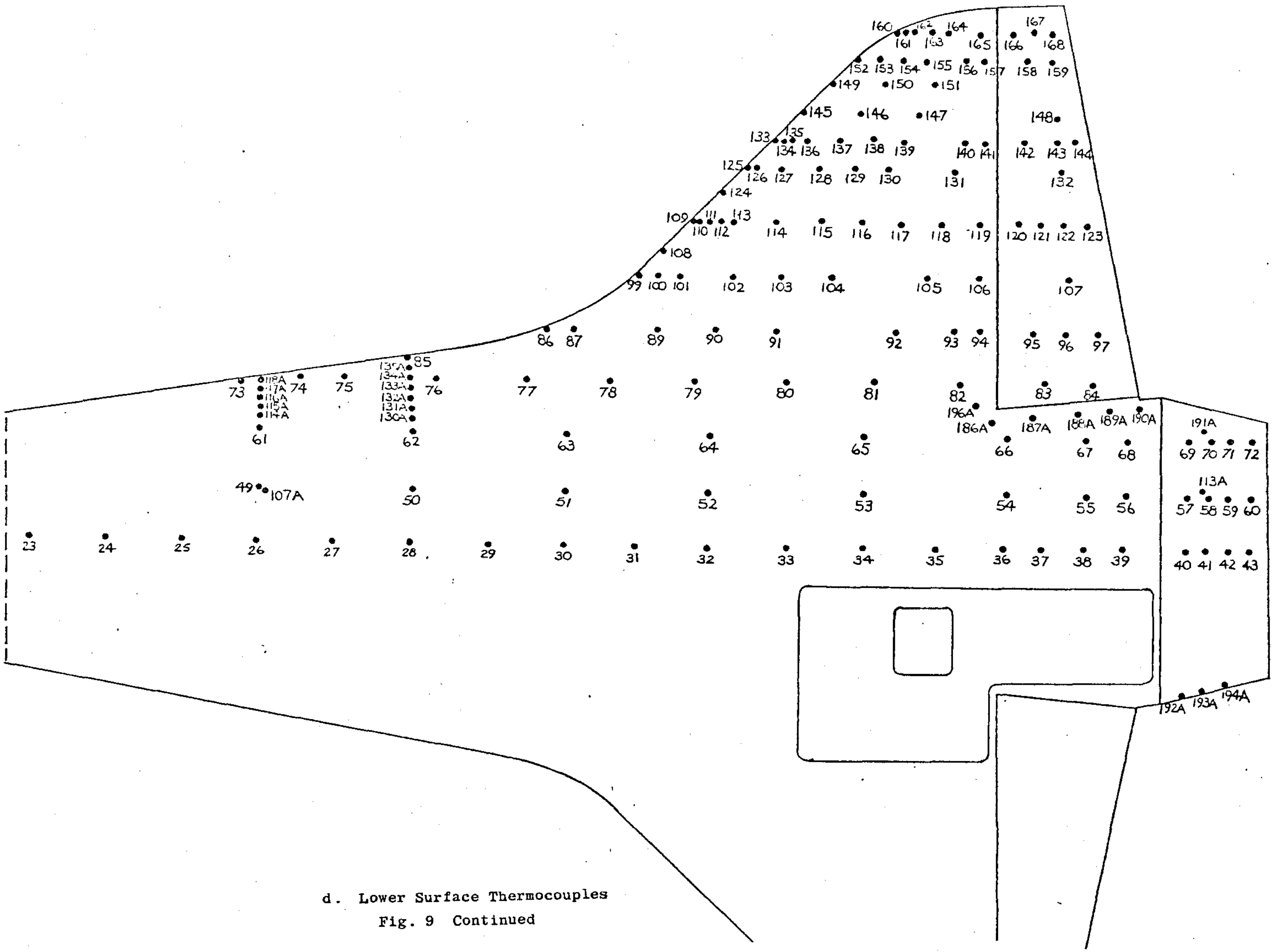
b. Nose and Canopy

Fig. 9 Continued

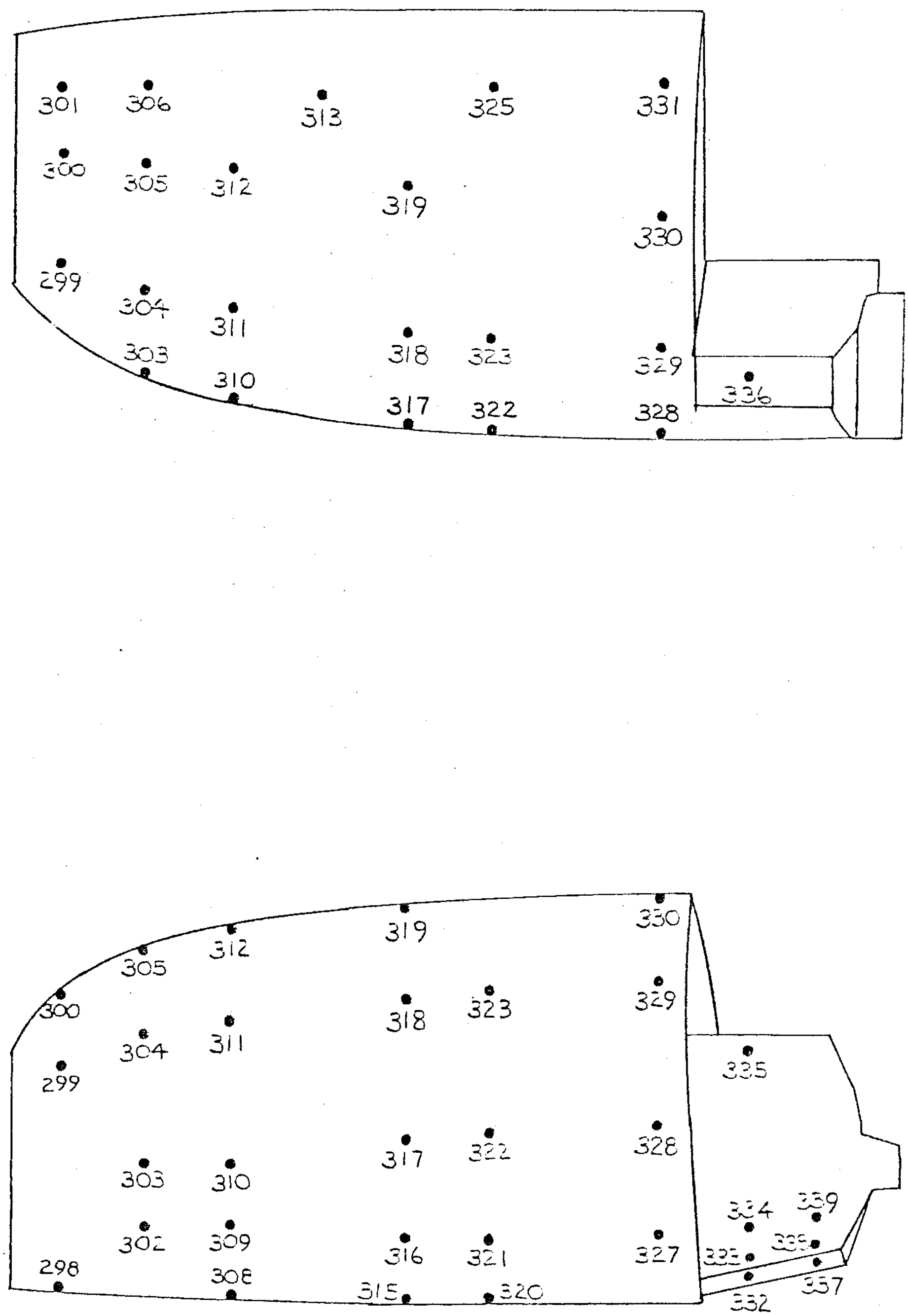


c. Upper Surface Thermocouples

Fig. 9 Continued

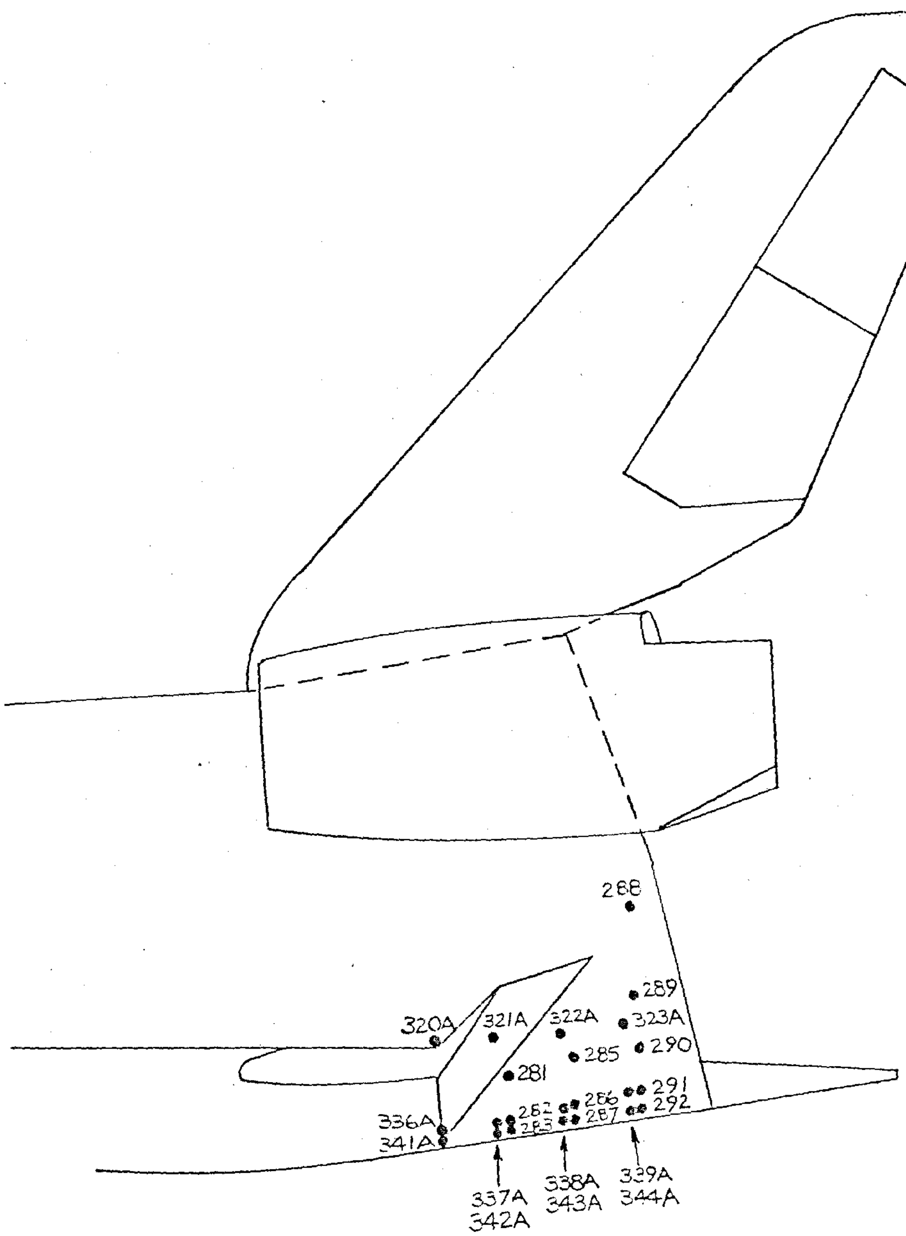


d. Lower Surface Thermocouples
Fig. 9 Continued



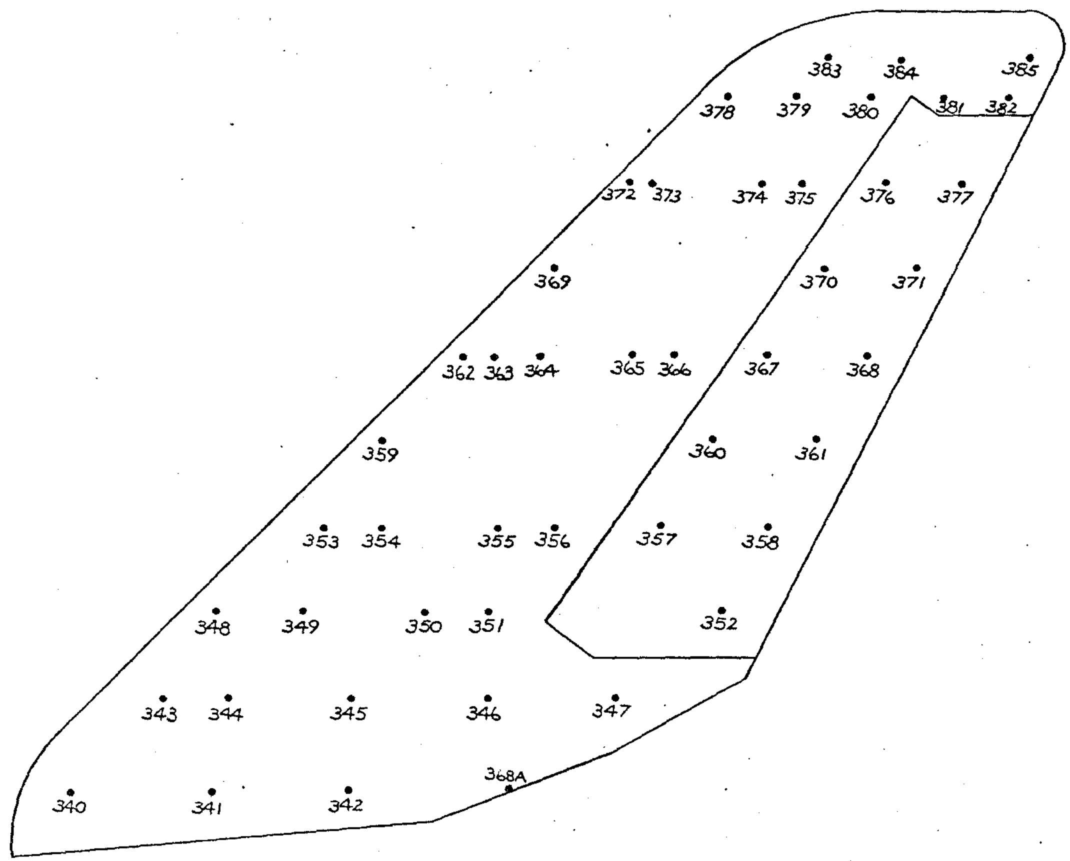
e. OMS Pod

Fig. 9 Continued

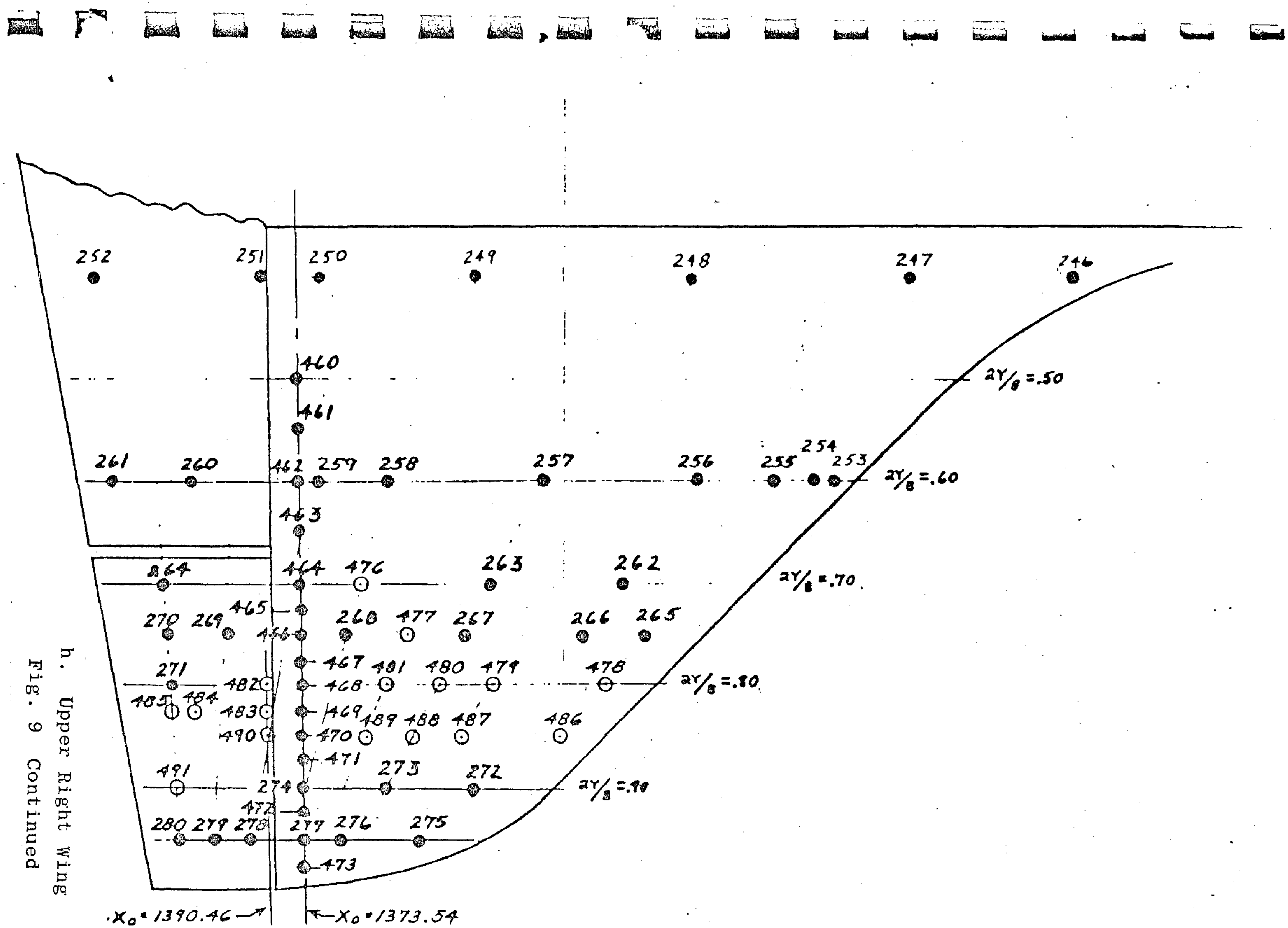


f. Aft Fuselage

Fig. 9 Continued

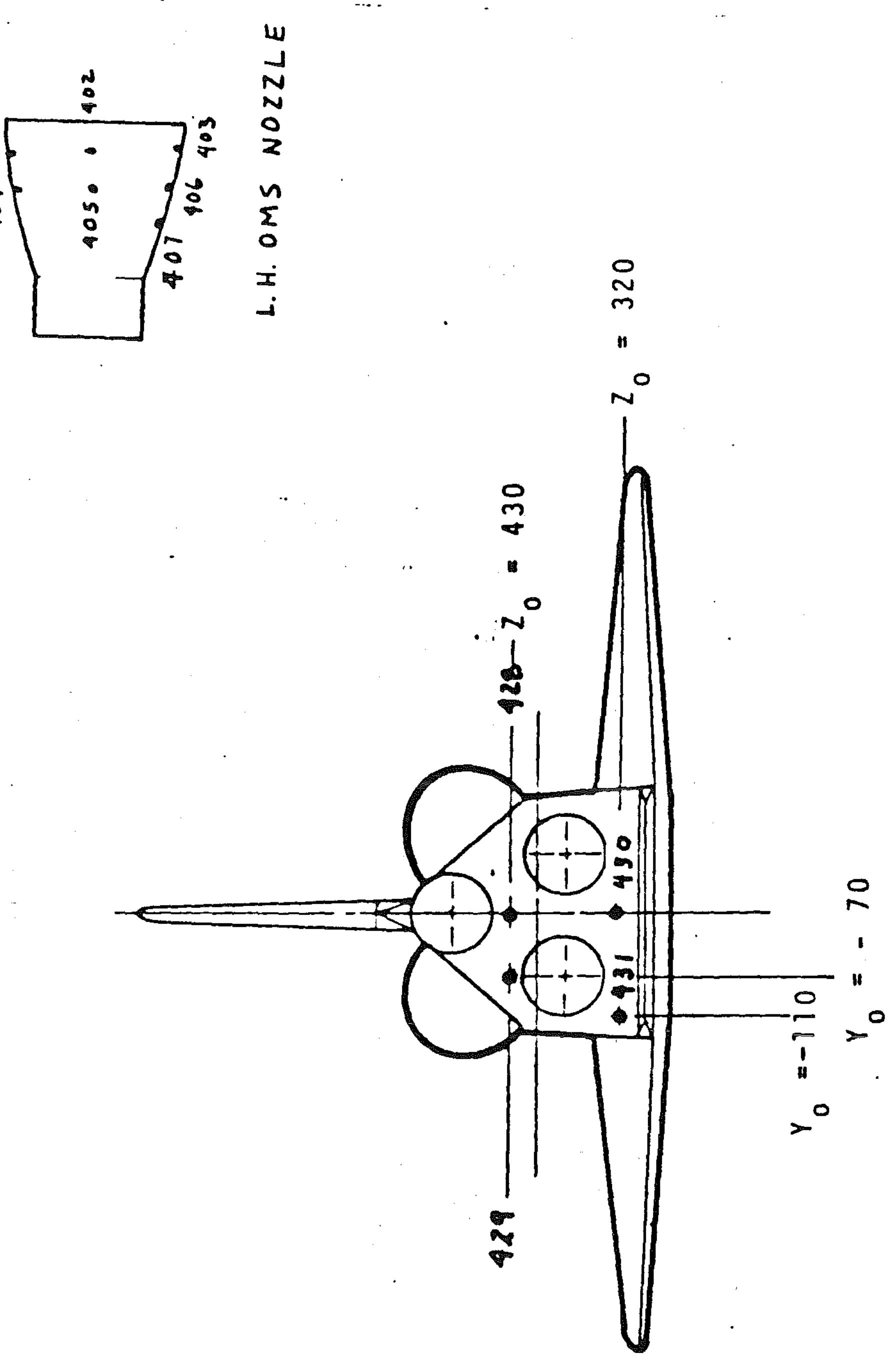


g. Vertical Tail
Fig. 9 Continued



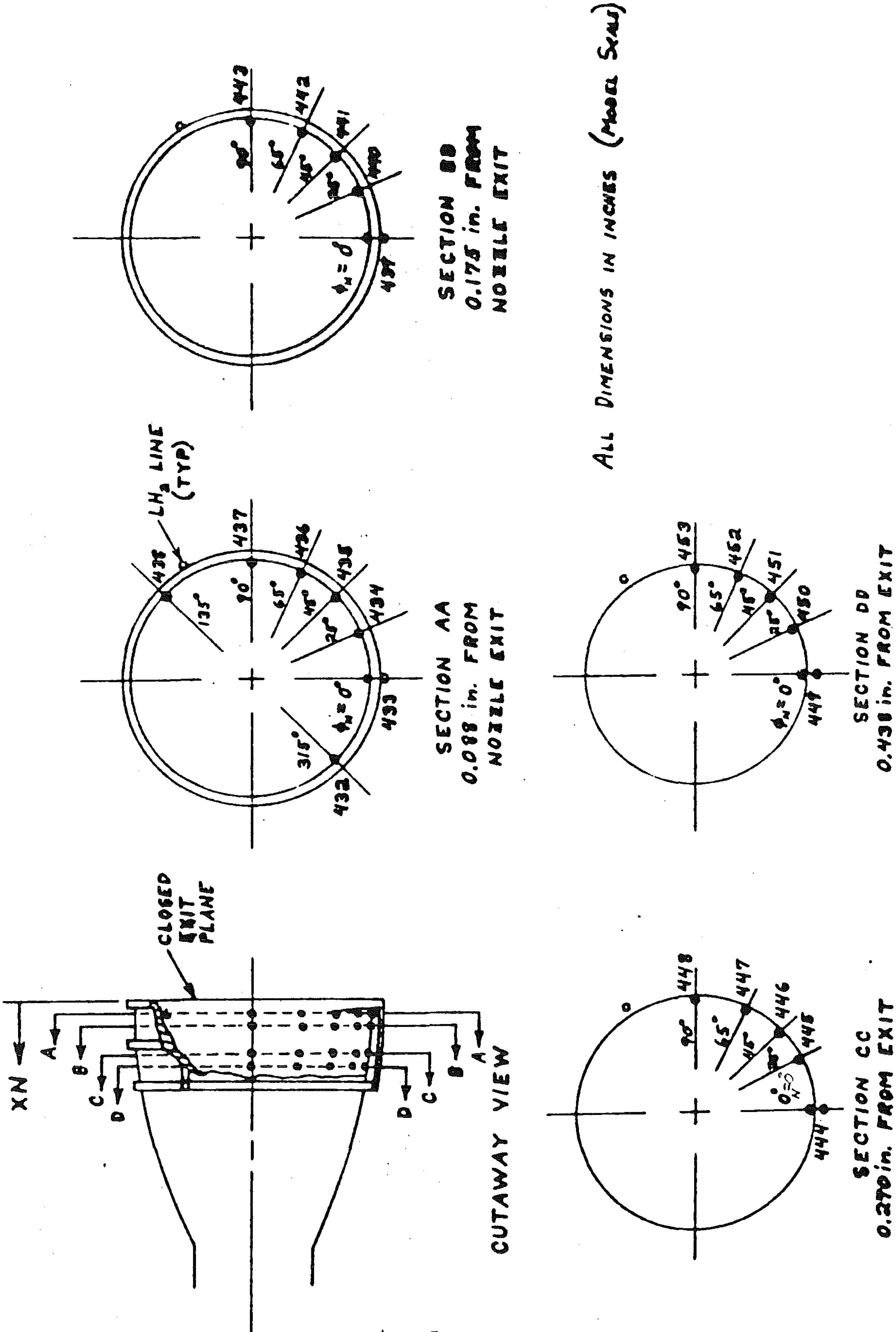
h. Upper Right Wing

Fig. 9 Continued



i. Nozzle Base Plate

Fig. 9 Continued



j. Lower Right SSME Nozzle

Fig. 9 Concluded

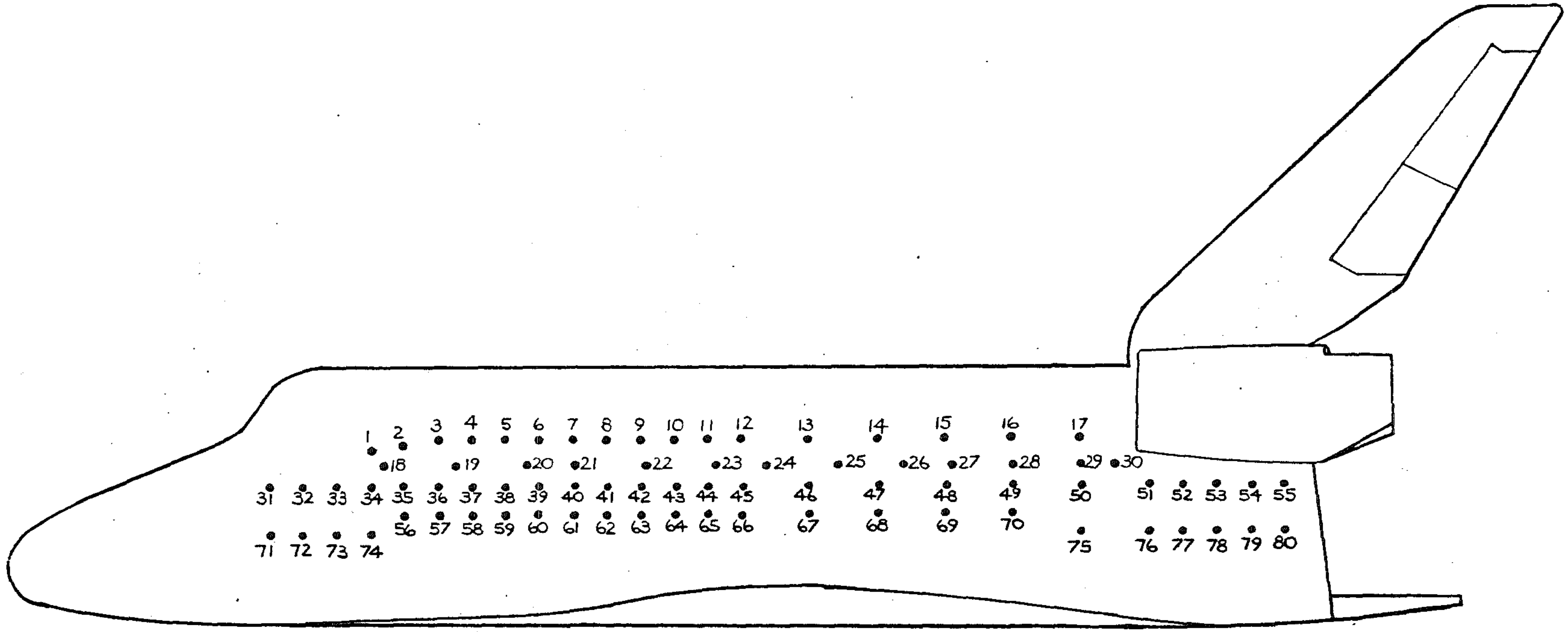
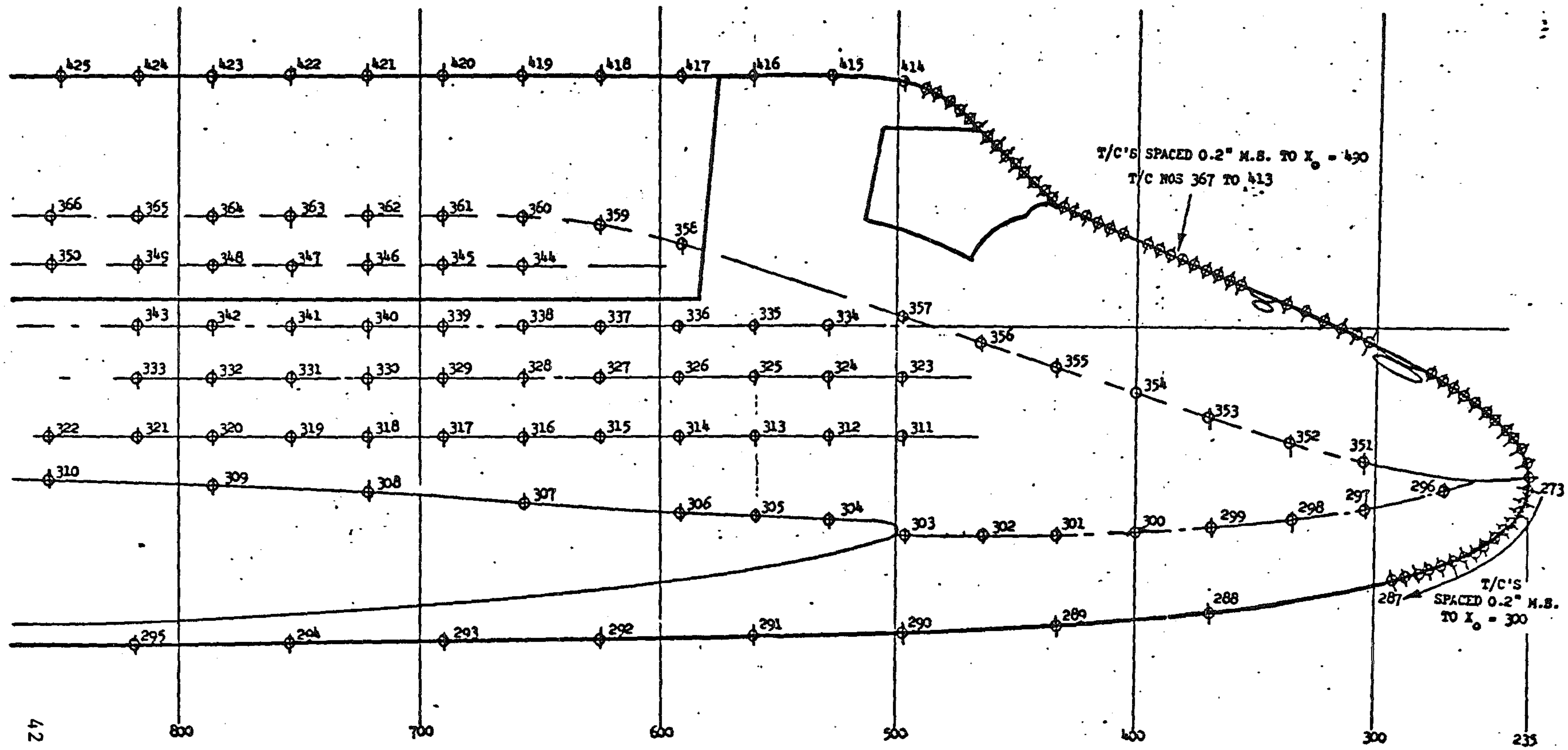
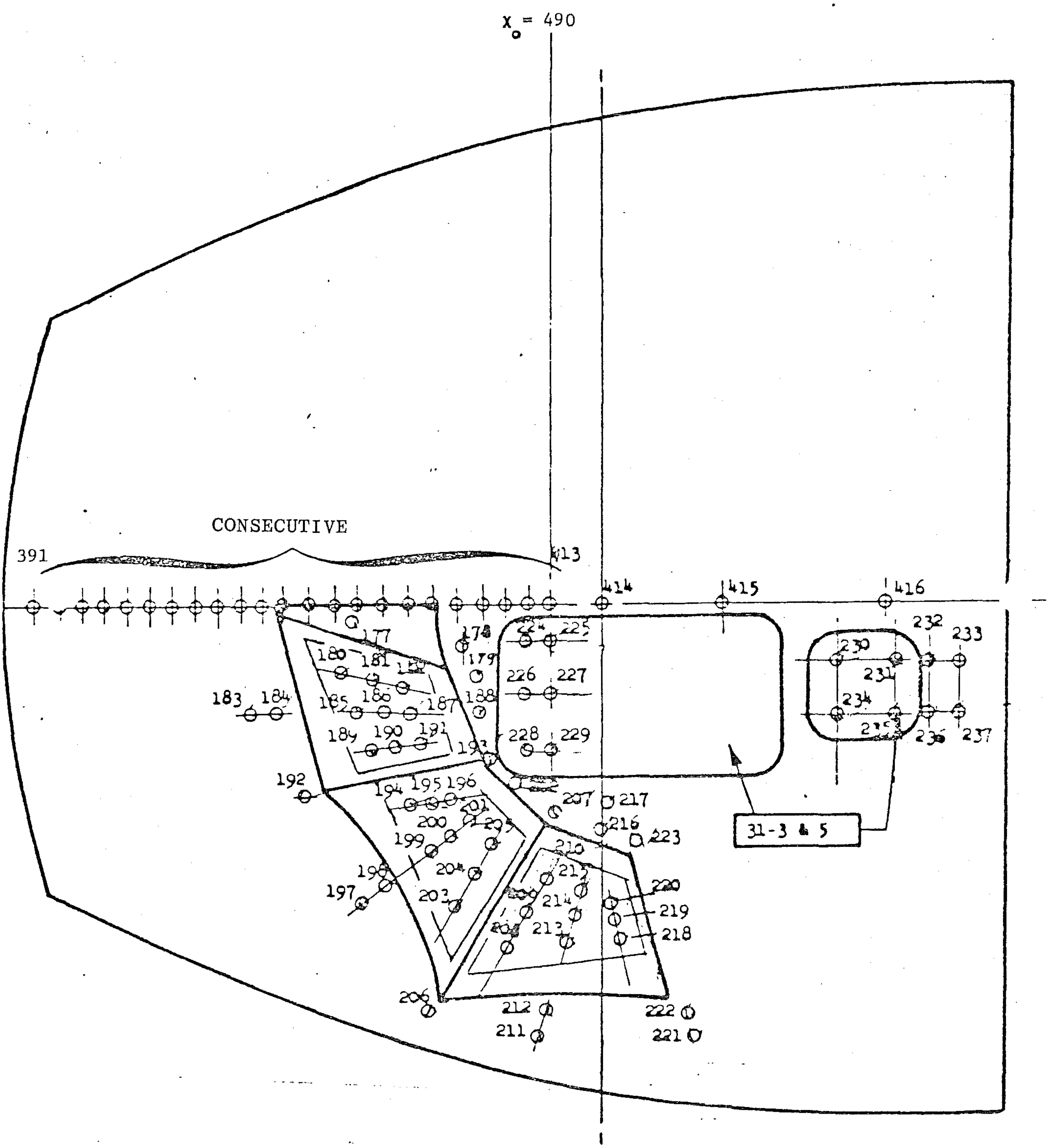


Fig. 10 Thermocouple Locations on 56-Ø Model



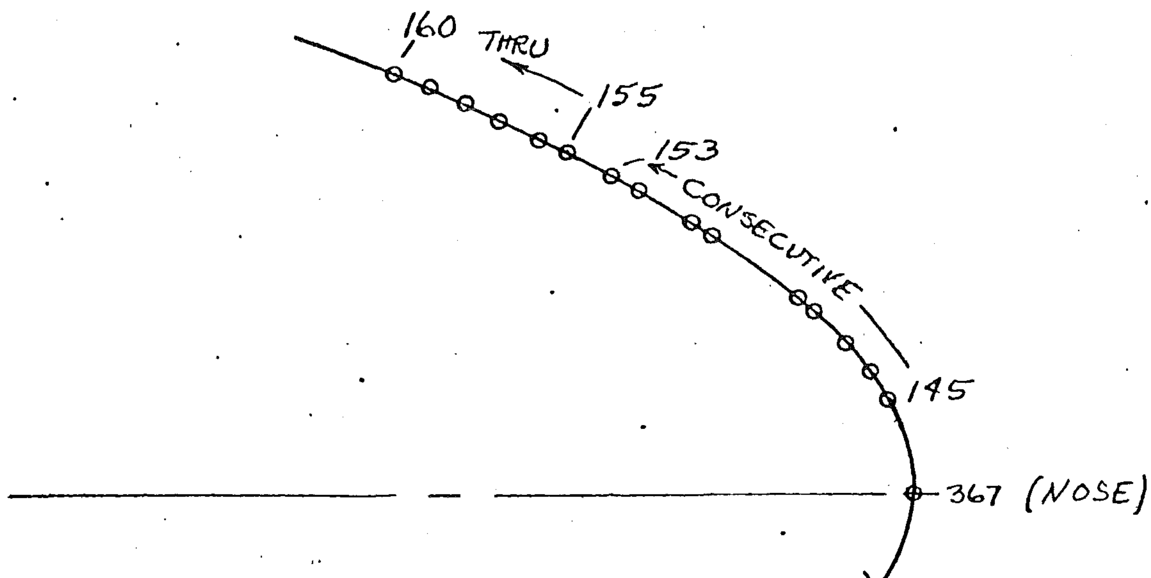
a. T/C Locations on Fuselage Right Side

Fig. 11 Thermocouple Locations on 83-Ø Model

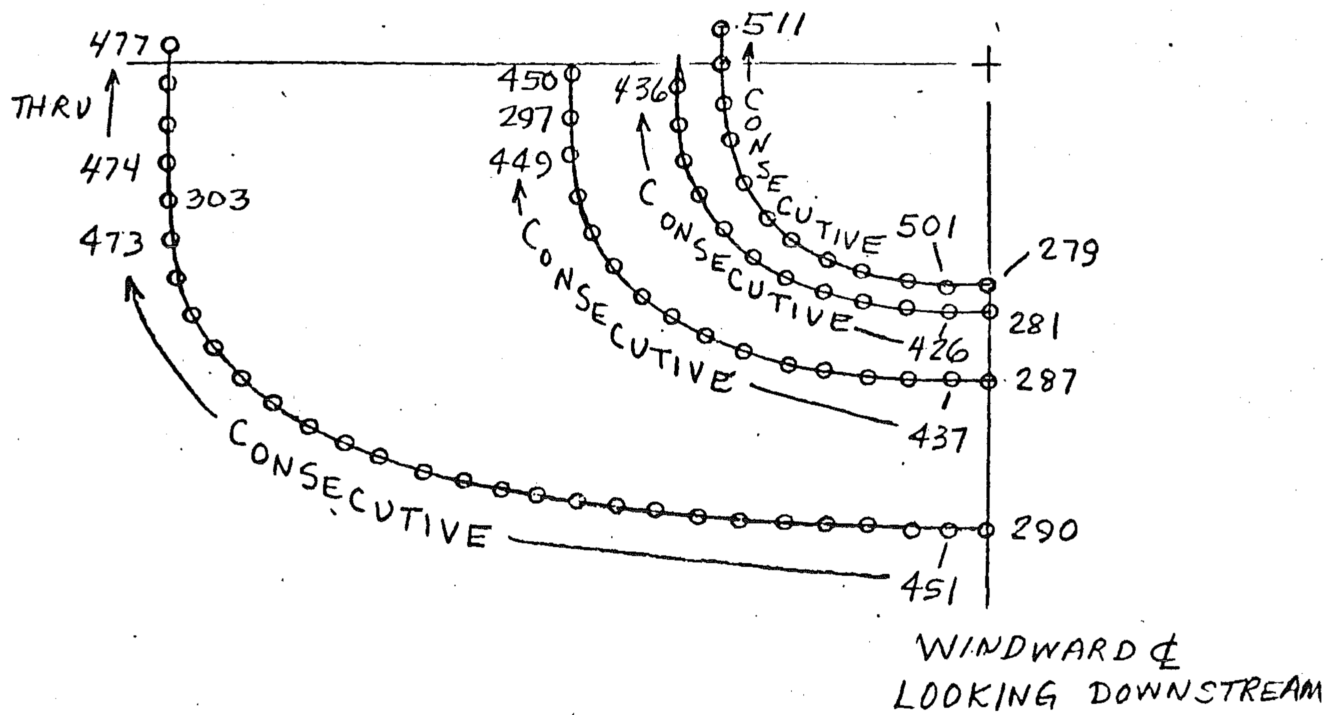


b. Canopy T/C Locations

Fig. 11 Continued

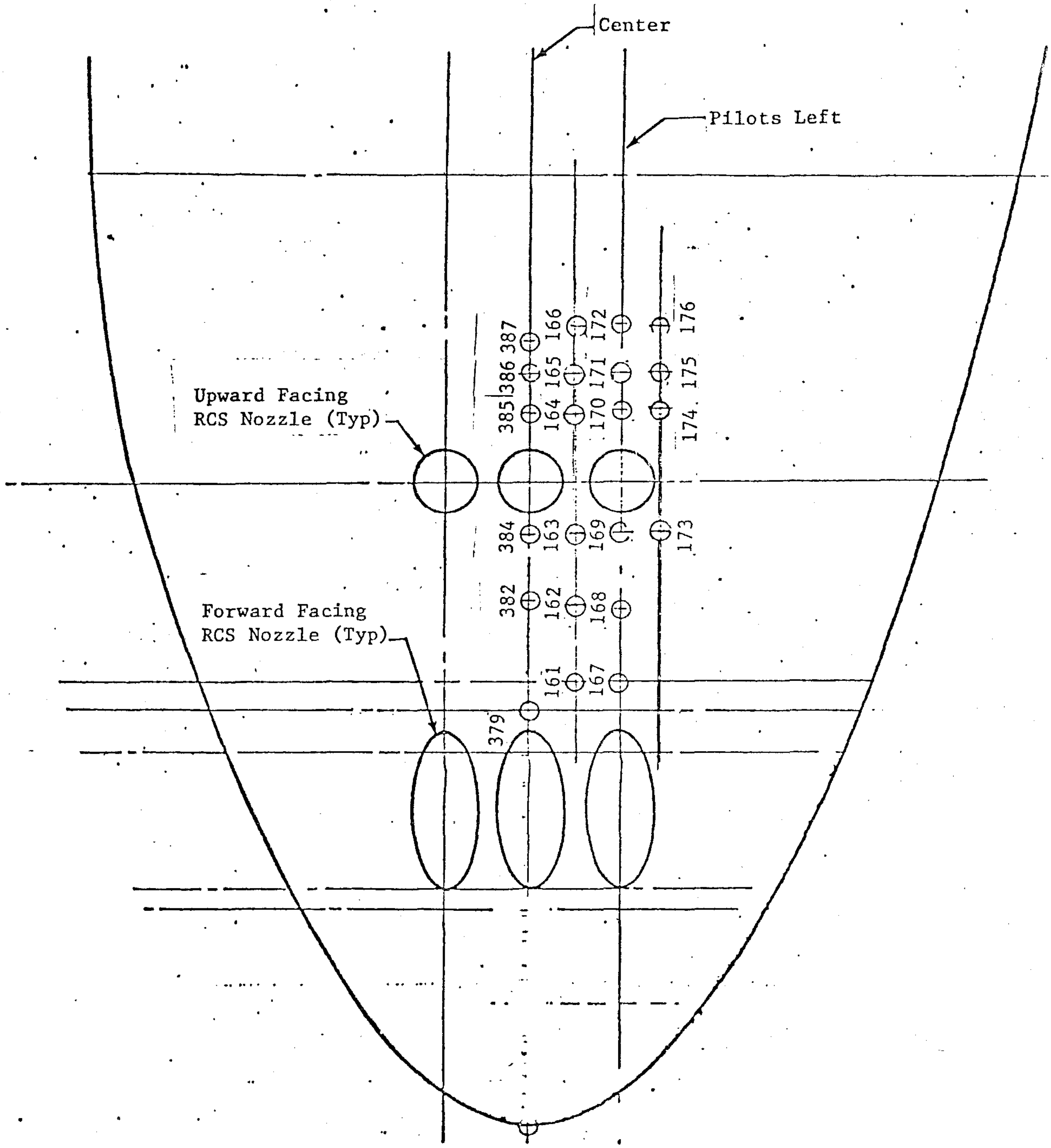


(b) LEFT SIDE RAY (TOP VIEW)



c. Radial Locations

Fig. 11 Continued



d. Upper Nose T/C Locations

Fig. 11 Concluded

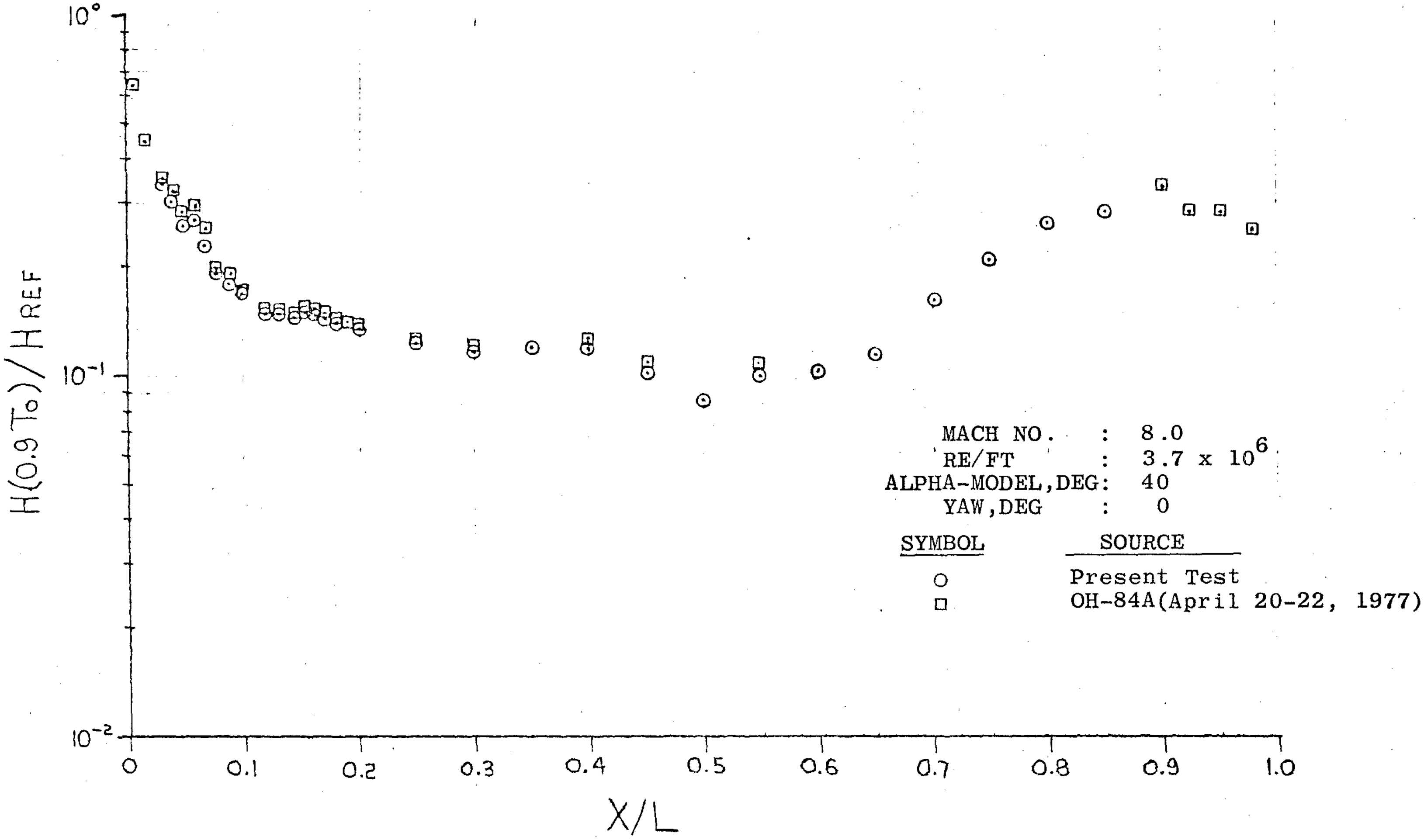


Fig. 12 Comparison of Current and Previous Test Results

APPENDIX II

TABLES

TABLE 1 CONFIGURATION CODES

NASA TEST CODE	MODEL CONFIGURATION CODE (See Fig. 8)	MODEL CONFIGURATION	TUNNEL	CONSTANT SETS
OH-84B	10	60-Ø BASE STING	B	111, 122, 133
OH-84B	20	60-Ø OFFSET STING	B	211, 222
IH-102	30	56-ØTS	A	311
IH-102	31	56-Ø	A	311
IH-102	40	83-Ø	A	411, 422
IH-102	50	60-Ø	A	511, 522, 533
IH-102	51	60-Ø	A	511, 522, 533
IH-102	60	60-ØTS	A	511, 522, 533
OH-105	70	60-Ø	B	711, 722, 733, 811
OH-105	80	83-Ø	B	911, 922

TABLE 2 60-Ø MODEL THERMOCOUPLE LOCATIONS

T/C No.	X/L	Full Scale			Model Scale			ϕ	Skin Thickness	Mat'l	Remarks
		X_o	Y_o	Z_o	$X_{from\ nose}$	Y	$Z_{from\ FRL}$				
1	0	235.0	0	–	0	0	–	0	.040	17-4	Bottom ℄
2	.005	241.47			.113				.032		
3	.01	247.93			.226				.033		
4	.02	260.87			.453				.040		
5	.03	273.80			.679				.040		
6	.04	286.73			.905				.040		
7	.05	299.67			1.132				.033		
8	.06	312.60			1.358				.035		
9	.07	325.53			1.584				.032		
10	.08	338.46			1.811				.032		
11	.09	351.40			2.037				.035		
12	.10	364.33			2.263				.037		
13	.12	390.20			2.716				.040		
14	.13	403.13			2.942				.038		
15	.14	416.06			3.169				.035		
16	.15	429.00			3.395				.036		
17	.16	441.93			3.621				.036		
18	.17	454.86			3.848				.035		
19	.18	467.79			4.074				.035		
20	.19	480.73			4.300				.035		
21	.20	493.66			4.527				.035		
22 C	.225	525.99			5.092				.035		
23	.25	558.32			5.658				.035		
24	.30	622.99			6.790				.035		
25	.35	687.66			7.922				.035		
26	.40	752.32			9.053				.034		
27 C	.45	816.99			10.185				.033		
28 C	.50	881.65			11.315				.032		
29 C	.55	946.32			12.448				.030		
30 C	.60	1010.9			13.580				.030		
31 C	.65	1075.6			14.711				.030		
32 C	.70	1140.3			15.843				.029		
33 C	.75	1204.9			16.975				.030		
34 C	.80	1269.6			18.106				.030		

TABLE 2 Continued

T/C No.	X/L	Full Scale X_o	Full Scale Y_o	Full Scale Z_o	Model Scale $X_{from\ nose}$	Model Scale Y	Model Scale $Z_{from\ FRL}$	ϕ	Skin Thickness	Mat'l	Remarks
35C	.85	1324.3	0	–	19.068	0	–	0	.029	17-4	Bottom ℄
36C	.90	1398.9			20.369				.031		
37C	.925	1431.3			20.935				.027		
38C	.950	1463.6			21.501				.027		
39C	.975	1495.9			22.067				.023		
40	1.015	1547.7			22.972				.030		
41	1.03	1567.1			23.312				.030		
42	1.045	1586.3			23.651				.028		
43	1.06	1605.0			23.977				.0265		
44	.05	299.67	25.0		1.132	.438		14	.032		Fuselage Bottom Surface
45	.10	364.33	20.0		2.263	.350		10	.036		
46	.15	429.0	24.0		3.395	.420		10	.035		
48	.20	493.66	50.0		4.527	.875		24	.025		
--											
50C	.50	881.65	46.8		11.316	.819		–	.028		
51C	.60	1010.9			13.580				.025		
52C	.70	1140.3			15.843				.030		
53C	.80	1269.6			18.106				.030		
54C	.90	1398.6			20.369				.028		
55C	.95	1463.6			21.501				.025		
56C	.975	1495.9			22.067				.028		
57	1.015	1547.7			22.972				.030		
58	1.03	1567.1			23.312				.030		
59	1.045	1586.5			23.651				.030		
60	1.060	1605.0			23.977				.031		
61C	.40	752.32	93.60		9.053	1.638			.032		
62C	.50	881.65			11.316				.031		
63C	.60	1010.9			13.580				.033		
64C	.70	1140.3			15.843				.029		
65C	.80	1269.6			18.106				.031		
66C	.90	1398.6			20.369				.030		
67C	.95	1463.6			21.501				.029		
68C	.975	1495.9			22.067				.028		

TABLE 2 Continued

T/C No.	X/L	Full Scale X_o	Y_o	Z_o	Model Scale $X_{from\ nose}$	Y	$Z_{from\ FRL}$	ϕ	Skin Thickness	Mat'l	Remarks
69	1.015	1547.7	93.6	–	22.972	1.638	–	–	.0275	17–4	Fus. Bottom Sur.
70	1.03	1567.1			23.312				.0285		
71	1.045	1586.5			23.651				.029		
72	1.06	1605.0			23.977				.027		
169	.01	247.93	0		.226	0		180	.033		Top ℄
170	.025	267.33			.565				.031		
171	.050	299.67			1.129				.035		
172	.075	332.0			1.694				.035		
173	.100	364.33			2.258				.034		
174	.125	396.66			2.283				.032		
175	.150	429.0			3.387				.032		
176	.160	441.93			3.613				.040		
177	.170	459.86			3.839				.040		
178	.180	467.79			4.064				.033		
179	.200	493.66			4.516				.036		
[illegible]	[illegible]	[illegible]			[illegible]						
[illegible]	[illegible]	[illegible]			[illegible]						
182	.40	752.32			9.053				.026		
183	.45	816.99			10.185				.026		
184	.50	881.65			11.316				.025		
185	.55	946.32			12.448				.026		
186	.60	1010.9			13.580				.025		
187	.65	1075.6			14.711				.024		
188	.70	1140.3			15.843				.025		
189	.75	1204.9			16.975				.0255		
190	.80	1269.6			18.106				.023		
191	–	–	6.00	452.0	–	.105	.910	–	.031		Window #1 Bott. Right
192			12.80	478.0		.224	1.365		.031		Top Right
193			21.20	464.9		.371	1.136		.030		Center
194			29.60	478.0		.518	1.365		.028		Top Left
195			34.30	452.0		.602	.910		.030		Bottom Right
196			40.40	452.0		.707	.910		.030		Window #2 Bottom Right
197			34.80	478.0		.609	1.365		.030		Top Right
198			44.80	464.9		.784	1.136		.030		Center

TABLE 2 Continued

T/C No.	X/L	Full Scale X_o	Full Scale Y_o	Z_o	Model Scale $X_{from\ nose}$	Model Scale Y	Model Scale $Z_{from\ FRL}$	ϕ	Skin Thickness	Mat'l	Remarks
199	–	–	43.20	478.0	–	.756	1.365	–	.030	17-4	Window #2 Top LT
200			59.20	452.0		1.036	.910		.029		Bottom Left
201			52.40	464.9		1.092	1.136		.029		Window #3 Center
202	.05	299.6	–	303.6	1.132	–	-1.687	22	.040		Fus. Side CCL
203				325.6			-1.302	35	.035		MHB
204				342.4			-1.008	42.5	.033		UT
205				378.4			-0.378	60	.033		45T
206	.076	332.2		350.0	1.720		-0.875	–	.035		RCS
207	.10	364.3	39.20	–	2.263	.686	–	20	.038		
208			52.00			.910	–	24.5	.035		CCL
209			–	317.6		–	-1.442	39	.035		MHB
210				410.0			0.175	119	.037		
211	.15	429.0	40.80	–	3.395	.714	–	20	.035		
212			62.00	–		1.085	–	25.5	.025		CCL
213			79.20	304.8		1.386	-1.666	40	.030		CCL
214			83.60	314.4		1.463	-1.498	45.5	.038		MHB
215	.20	493.6	65.80	287.20	4.527	1.148	-1.974	31.5	.022		CCL
216			75.60	292.0		1.323	-1.890	35	.022		CCL
217			85.20	298.8		1.491	-1.771	40	.020		CCL
218			–	320.0		–	-1.400	51	.035		MHB
219			–	360.0			-0.700	67.5	.030		UT
220C			–	410.0			0.175	96.5	.031		Upper Fuselage
223	.40	752.32	–	–	9.053	–	–	157.5	.034		Upper Fuselage
224	.45	816.99			10.185				.034		
225	.50	881.65			11.316				.034		
226	.55	946.32			12.448				.035		
227	.60	1010.9			13.580				.034		
228	.65	1075.6			14.711				.0325		
229	.70	1140.3			15.843				.030		
230	.75	1204.9			16.975				.030		
231	.80	1269.6			18.106				.032		

TABLE 2 Continued

T/C No.	X/L	Full Scale X_o	Full Scale Y_o	Full Scale Z_o	Model Scale $X_{from\ nose}$	Model Scale Y	Model Scale $Z_{from\ FRL}$	ϕ	Skin Thickness	Mat'l	Remarks
~~[illegible]~~	~~[illegible]~~	~~[illegible]~~			~~[illegible]~~			~~[illegible]~~		17-4	Upper Fuselage
234	.40	752.32	-	-	9.053	-	-	135	.030		
235	.45	816.99			10.185				.030		
236	.50	881.65			11.316				.036		
237	.55	946.32			12.448				.035		
238	.60	1010.9			13.580				.031		
239	.65	1075.6			14.711				.032		
240	.70	1140.3			15.843				.030		
241	.75	1204.9			16.975				.032		
242	.80	1269.6			18.106				.032		
288 C	.975	1496.0	-	381.2	22.068	-	-0.329	-	0.030		Aft Fuselage Side
388	.40	752.32	-	445.0	9.053		0.788	114	.031		Upper Fuselage Side
389	.45	816.99			10.185				.033		
390	.50	881.65			11.316				.036		
391	.55	946.32			12.448				.0345		
392	.60	1010.9			13.580				.0335		
393	.65	1075.6			14.711				.0345		
394	.70	1140.3			15.848				.034		
395	.75	1204.9			16.975				.036		
396	.80	1269.6			18.106				.034		

TABLE 2 Continued

Wing T/C Locations

T/C No.	$\frac{2Y}{B}$	Full Scale X/C	X_o	Y_o	Model Scale X from L.E.	Y		Elevon T/C	Skin Thickness	Mat'l	Remarks
73C	.30	0		140.5	0	2.459			.020	17-4	Wing Lower Sur.
74C		.05			.670				.020		
75C		.10			1.340				.026		
76C		.20			2.680				.031		
77C		.30			4.020				.030		
78C		.40			5.360				.031		
79C		.50			6.700				.030		
80C		.60			8.040				.030		
81C		.70			9.380				.031		
82C		.80			10.720				.030		
83		.90			12.060			X	.0305		
84		.95			12.730			X	.031		
86C	.40	0		187.3	0	3.287			.022		
87C		.05			.438				.031		
88C		.10			.876				.031		
89C		.20			1.753				.030		
90C		.30			2.629				.031		
91C		.40			3.506				.029		
92C		.60			5.258				.033		
93C		.70			6.135				.033		
94C		.75			6.573				.030		
95		.85			7.449				.0295		
96		.90			7.888			X	.026		
97		.95			8.326			X	.0275		
98C	.45	0		210.7	3.688			X	.030		
99C	.50	0		234.1	0	4.098			.027		
100C		.05			.364				.029		
101C		.10			.727				.030		
102C		.20			1.454				.031		
103C		.30			2.181				.031		
104C		.40			2.098				.031		
105C		.60			4.362				.032		
106C		.70			5.089				.031		

TABLE 2 Continued

Wing T/C Locations

T/C No.	2Y/B	Full Scale			Model Scale			Elevon T/C	Skin Thickness	Mat'l	Remarks
		X/C	X_o	Y_o	X from L.E.	Y					
107	.50	.90		234.1	6.543	4.098		X	.0285	17-4	Wing Lower Sur.
108C	.55	0		257.6	0	4.508			.026		
109C	.60	0		281.0	0	4.918			.024		
110C		.025			.157				.029		
111C		.05			.314				.028		
112C		.075			.470				.030		
113C		.10			.627				.031		
114C		.20			1.254				.031		
115C		.30			1.882				.033		
116C		.40			2.059				.032		
117C		.50			3.136				.032		
118C		.60			3.763				.032		
119C		.70			4.390				.031		
120		.80			5.018			X	.030		
121		.85			5.331			X	.0305		
122		.90			5.695			X	.0295		
123		.95			5.958			X	.0295		
124C	.65	0		309.4	0	5.327			.026		
125C	.70	0		327.8	0	5.737			.017		
126C		.025			.133				.024		
127C		.10			.531				.032		
128C		.20			1.061				.036		
129C		.30			1.592				.036		
130C		.40			2.123				.035		
131		.60			3. 84				.035		
132		.90			4.776			X	.031		
133	.75	0		352.8	0	6.174			.028		
134		.025			.121				.028		
135		.05			.241				.030		
136		.10			.483				.032		
137		.20			.965				.032		
138		.30			1.448				.035		
139		.40			1.930				.034		
140		.60			2.895				.033		

TABLE 2 Continued

Wing T/C Locations

T/C No.	$\frac{2Y}{B}$	Full Scale X/C	X_o	Y_o	Model Scale X from L.E	Y		Elevon T/C	Skin Thickness	Mat'l	Remarks
141C	.75	.70		352.8	3.378	6.174			.031	17-4	Wing Lower Surf.
142		.80			3.860			X	.027		
143		.90			4.343			X	.0305		
144		.95			4.584			X	.0295		
145	.80	0		374.6	0	6.557			.024		
146		.20			.868				.032		
147		.40			1.737				.031		
148		.90			3.908			X	.0305		
149	.85	0		398.1	0	6.967			.028		
150		.20			.772				.031		
151		.40			1.544				.030		
152	.90	0		421.4	0	7.376			.028		
153		.10			.338				.030		
154		.20			.675				.031		
155C		.30			1.013				.031		
156		.50			1.689				.031		
157C		.60			2.026				.032		
158		.80			2.702			X	.0285		
159		.90			3.039			X	.028		
160	.95	0		444.9	0	7.786			.030		
161		.05			.138				.031		
162		.10			.276				.030		
163		.20			.552				.032		
164		.30			.827				.031		
165		.50			1.379				.030		
166		.70			1.931			X	.0295		
167		.80			2.206			X	.030		
168		.90			2.482			X	.0295		
246	.400	.05		187.3	.483	3.278			.024		Wing Upper Surface
247		.20			1.753				.028		
248		.40			3.506				.024		

TABLE 2 Continued

WING T/C LOCATIONS

T/C No.	$\frac{2Y}{B}$	X/C	Full Scale Xo	Full Scale Yo	Model Scale Y From LE	Model Scale Y		Elevon T/C	Skin Thickness	Mat'l	Remarks
249	.40	.60		187.3	5.258	3.278			.020	17-4	Wing Upper Surf.
250		.75			6.573				.030		
251		.80			7.011			x	.029		
252		.95			8.326			x	.025		
253	.60	.025		281.0	.157	4.918			.009		
254		.05			.314				.011		
255		.10			.627				.021		
256		.20			1.254				.025		
257		.40			2.509				.027		
258		.60			3.763				.024		
259		.75			4.703				.025		
260		.85			5.331			x	.027		
261		.95			5.958			x	.020		
262	.70	.20		327.83	1.061	5.737			.024		
263		.40			2.123				.025		
264		.90			4.776			x	.028		
265	.75	.10		352.25	.483	6.147			.023		
266		.40			.965				.023		
267		.40			1.930				.025		
268		.60			2.895				.022		
269		.80			5.860			x	.024		
270		.90			4.430			x	.028		
271	.80	.90		374.65	3.908	6.557		x	.029		
272	.90	.20		421.99	.675	7.376			.025		
273		.40			1.351				.025		
274		.60			2.026				.030		
275	.95	.20		444.91	.552	7.786			.023		
276		.40			1.103				.030		
277		.50			1.379				.025		
278		.70			1.930			x	.028		
279		.80			2.206			x	.029		
280		.90			2.481			x	.028		

TABLE 2 Continued

OMS Pod T/C Locations

T/C No.	X/L	Full Scale X_o	Full Scale Y_o	Full Scale Z_o	Model Scale X_{from} Pod LE	Model Scale	Model Scale Z from FRL		Skin Thickness	Mat'l	Remarks
~~293~~		~~[illegible]~~	~~[illegible]~~	~~[illegible]~~						17-4	
~~294~~			~~[illegible]~~	~~[illegible]~~							
~~295~~			~~[illegible]~~	~~[illegible]~~							
~~296~~			~~[illegible]~~	~~[illegible]~~							
~~297~~			~~[illegible]~~	~~[illegible]~~							
298		1325	106.9	428.6*					.030		
299			98.77	489.2					.033		
300			67.73	511.3					.030		
301			48.78	506.7					.028		
302		1350	123.6	440.4					.024		
303			132.0	458.6					.030		
304			108.9	498.5					.032		
305			69.5	524.4					.029		
306			47.3	515.5					.031		
~~307~~			~~[illegible]~~	~~[illegible]~~							
308		1375	111.6	421.6					.016		
309			130.0	440.0					.023		
310			139.6	460.0					.035		
311			113.8	503.4					.028		
312			72.4	531.0					.031		
313		1400	48.28	523.4					.027		
~~314~~			~~[illegible]~~	~~[illegible]~~							
315		1425	115.0	415.1					.031		
316			133.7	437.7					.030		
317			147.7	466.3					.038		
318			119.7	508.6					.027		
319			77.34	536.5					.030		
320		1450	117.48	418.20					.023		
321			134.5	436.0					.029		
322			149.8	468.2					.033		
323			122.2	511.1					.025		
~~324~~			~~79.8~~	~~[illegible]~~							
325			48.3	526.6					.027		
~~326~~		~~[illegible]~~	~~[illegible]~~	~~[illegible]~~							

TABLE 2 Continued

OMS Pod T/C Locations

T/C No.	X/L	Full Scale X_o	Y_o	Z_o	Model Scale X from Pod LE	Y	Z from FRL		Skin Thickness	Mat'l	Remarks
327		1500	136.7	437.0					.029	17-4	
328			151.2	470.4					.036		
329			125.6	514.0					.031		
330			89.5	539.4					.031		
331			55.7	532.3					.034		
332		1525	–	424.0					.029		Downward Firing RCS
333			–	431.0					.034		
334				440.0					.035		
335				493.0					.029		
336			133.0	–					.030		Upward Firing RCS
337		1545	–	428.0					.022		Downwd Firing RCS
338				434.0					.027		
339				443.0					.039		

TABLE 2 Continued

VERTICAL TAIL T/C LOCATIONS

T/C No.	Z/BV	X/C	Full Scale		Model Scale			Rudder T/C	Skin Thickness	Mat'l	Remarks
			Xo	Zo	X from L.E.	Z from FRL					
340	.10	.10							.0315	17-4	External Surface
341		.30							.0305		
342		.50							.0295		
343	.20	.10							.031		
344		.20							.0302		
345		.40							.0313		
346		.60							.031		
347		.80							.0315		
348	.30	.05							.0297		
349		.20							.031		
350		.40							.031		
351		.50							.0318		
352		.90						x	.030		
353	.40	.10							.0305		
354		.20							.0315		
355		.40							.0315		
356		.50							.0308		
357		.70						x	.029		
358		.90						x	.0298		
359	.50	.05							.0285		
360		.70						x	.028		
361		.90						x	.0315		
362	.60	.05							.029		
363		.10							.0295		
364		.20							.0303		
365		.40							.0318		
366		.50							.0315		
367		.70						x	.028		
368		.90						x	.030		
369	.70	.05							.0275		
370		.70						x	.0275		
371		.90						x	.029		
372	.80	.05							.029		
373		.10							.0293		

TABLE 2 Continued

VERTICAL TAIL T/C LOCATIONS

T/C No.	Z/BV	Full Scale			Model Scale			Rudder T/C	Skin Thickness	Mat'l	Remarks
		X/C	X_o	Z_o	X_{from} L.E.	Z_{from} FRL					
374	.80	.40							.031	17-4	External Surface
375	↓	.50							.0325	↓	↓
376	↓	.70						X	.028	↓	↓
377	↓	.90						X	.029	↓	↓
378	.90	.10							.031	↓	↓
379	↓	.30							.0305	↓	↓
380	↓	.50							.032	↓	↓
381	↓	.70							.0308	↓	↓
382	↓	.90							.0298	↓	↓
383	.95	.30							.0313	↓	↓
384	↓	.50							.0315	↓	↓
385	↓	.90							.033	↓	↓
397C									.0318	17-4	Speed Brake Cavity
398C									.0312		↓
399C									.0312		↓
400C									.0312		↓

TABLE 2. Continued

Upper Wing T/C Locations

T/C No.	$\frac{2Y}{B}$	FULL SCALE X_o	FULL SCALE Y_o	MODEL SCALE X_o	MODEL SCALE Y_o	SKIN THICKNESS, IN.	MAT'L	REMARKS
460	.500	1373.54	234.17	24.036	4.097	.0280	17-4	Wing Upper Surf.
461	.550		257.587		4.507	.0305		
462	.600		281.004		4.917	.0290		
463	.650		304.421		5.327	.0290		
464	.700		327.838		5.751	.0300		
465	.725		339.546		5.942	.0290		
466	.750		351.255		6.146	.0270		
467	.775		362.963		6.351	.0240		
468	.800		374.672		6.556	.0240		
469	.825		386.380		6.761	.0240		
470	.850		398.089		6.966	.0250		
471	.875		409.797		7.171	.0260		
472 **	.925		433.214		7.581	.0270		
277	.950		444.923		7.786	.0250		
473	.975		456.631		7.991	.0200		

* SPAN = 936.68 in full scale

** T/C 274 REF. 2Y/B = .900

T/C NO.	$\frac{2Y}{B}$	FULL SCALE X/C	FULL SCALE Y_o	MODEL SCALE $X_{FROM\ LE}$	MODEL SCALE Y_o	Elevon T/C	SKIN THICK.	MAT'L	REMARKS
476	.700	.60	327.83	3.125	5.737		.0300	17-4	Wing Upper Surf.
477	.750	.50	351.25	2.411	6.147		.0290		
478	.800	.10	374.69	.435	6.557		.0310		
479		.30		1.305			.0320		
480		.40		1.740			.0320		
481		.50		2.171			.0320		
482		-		24.33 X_o		X	.0250		
483	.825	-	386.00	24.33 X_o	6.756	X	.0280		
484		.85		3.485		X	.0250		
485		.90		3.690		X	.0290		
486	.850	.10	397.94	.386	6.964		.0320		
487		.30		1.158			.0300		
488		.40		1.544			.0300		
489		.50		2.000			.0300		
490		-		24.33 X_o		X	.0290		
491	.900	.90	421.50	3.033	7.376	X	.0290		

TABLE 2. Continued

ADDITIONAL T/C LOCATIONS

T/C NO.	MODEL SCALE X_o	Y_o	Z_o	SKIN THICKNESS	MATERIAL	LOCATION
37A	4.553	0.252	-	.032	17-4	Lower Nose (LH)
38A	4.541	0.428	5.524	.033		
39A	4.515	-	5.696	.036		
41A	5.626		6.002	.031		
45A	6.361	1.041	5.266	.028		
46A		-	5.470	.030		
47A		1.230	5.673	.031		
65A	8.610	0.388	4.893	.030		
70A	8.610	1.681	5.388	.030		
107A	13.170	0.780	4.809	.024		Lower Mid Fuselage (LH)
114A	13.207	1.782	4.977	.031		
115A	13.107	1.962	-	.024		
116A		2.142	-	.020		
117A		2.322	-	.017		
118A		2.448	-	.025		
130A	15.356	1.837	4.882	.023		
131A	-	2.046	-	.029		
132A		2.250	-	.028		
133A		2.453	-	.026		
134A		2.663	-	.023		
135A		2.816	5.226	.027		
186A	24.329	1.819	4.681	.030		Lower Aft Fuselage
187A	24.925	1.883	-	.031		
188A	25.476	1.911	-	.028		
189A	25.923	1.981	-	.025		
196A	24.015	2.128	-	.028		
197A	24.480	2.459	-	.032		Lower Elevon (LH)
320A	24.576	-	5.565	.0295		Aft Fuselage & Elevon Split Line (LH)
321A	24.913	-		.0265		
322A	25.476	-		.027		
323A	26.038	-		.029		
336A	24.576	-	4.902	.030		
337A	24.913	-		.031		
338A	25.575	-		.028		
339A	26.138	-		.026		
341A	24.576	-	4.692	.030		
342A	24.913	-	4.692	.032		
343A	25.475	-	4.722	.031		
344A	26.038	-	4.759	.031		
249A	10.859	1.988	-	.030*		Upper Wing (RH)
250A	11.983		-	.028		
251A	13.107		-	.030		
252A	14.195		-	.022		
253A	17.545	1.970	-	.026		
254A	19.941	2.049	-	.018		
255A	22.330	2.047	-	.029		
256A	14.195	2.459	-	.020		

TABLE 2 Concluded

ADDITIONAL T/C LOCATIONS

T/C NO.	MODEL SCALE X_o	Y_o	Z_o	SKIN THICKNESS	MATERIAL	LOCATION
257A	15.535	2.459	4.759	.027	17-4	Upper Wing (RH)
258A	16.875		-	.020		
259A	18.215		-	.016		
260A	19.555		-	.028		
261A	20.895		-	.025		
262A	22.235		-	.030		
263A	23.576		-	.029		
279A	24.080	5.138	-	.030*		
113A	27.268	0.928	-	.030		Lower Body Flap
191A	27.268	1.819	-	.028		
314A	27.274	0	5.122	.0255		Upper Body Flap
315A	28.017	0	-	.019		
316A	27.275	0.875	5.224	.0295		
317A	28.017	0.875	-	.028		
318A	27.275	1.837	5.122	.0295		
319A	28.017	1.697	-	.0295		
192A	26.994	-	5.064	.031		Body Flap, Edge
193A	27.265	-	5.092	.0305		
194A	27.639	-	5.106	.031		
368A	26.091	0	9.303	.0305		Vertical Tail
87A	9.799	1.709	7.781	.031		Upper Mid Fuselage (LH)
88A	9.705	1.101	8.431	.026		
89A	9.717	0.672	6.654	.031		
102A	10.806	1.638	8.089	.023		
103A	10.806	0.867	8.523	.015		
122A	13.077	1.684	-	.0252		Upper Mid Fuselage (LH)
124A	13.107	1.128	-	.0308		
125A	13.077	0.868	-	.029		
126A	13.107	0.560	-	.0285		
127A	13.107	0.280	-	.0245		
139A	15.347	1.584	-	.0337		
140A	15.347	0.868	-	.0291		
404A	17.574	1.572	-	.0301		
405A	17.549	1.120	-	.0322		
406A	17.574	0.868	-	.0285		
407A		0.560	-	.0284		
408A		0.280	-	.0260		
410A	19.845	1.572	-	.0334		
155A	22.000	1.572	-	.0307		
156A	22.000	0.868	-	.0264		
157A	22.640	1.582	-	.0305		
158A		1.218	-	.0248		
159A		0.868	-	.0264		
160A		0.308	-	.0306		
36A	22.610	0.014	-	.0278		

*Normal Value; Skin Thickness Not Measured

TABLE 3 56-Ø MODEL THERMOCOUPLE LOCATIONS

T/C No.	b, in.	X/L	Z_o
1	0.0215	0.275	437.5
2	0.0210	0.300	442.0
3	0.0217	0.325	445.0
4	0.0215	0.350	
5	0.0212	0.375	
6	0.0217	0.400	
7	0.0215	0.425	
8	0.0218	0.450	
9	0.0219	0.475	
10	0.0220	0.500	
11	0.0220	0.525	
12	0.0222	0.550	
13	0.0220	0.600	
14	0.0220	0.650	
15	0.0228	0.700	
16	0.0220	0.750	
17	0.0230	0.800	445.0
18	0.0190	0.285	420.0
19	0.0189	0.337	
20	0.0189	0.390	
21	0.0190	0.426	
22	0.0200	0.478	
23	0.0200	0.530	
24	0.0205	0.567	
25	0.0205	0.620	
26	0.0205	0.670	
27	0.0207	0.705	420.0

T/C No.	b, in.	X/L	Z_o
28	0.0203	0.750	420.0
29	0.0202	0.800	420.0
30	0.0160	0.824	420.0
31	0.0210	0.200	400.0
32	0.0199	0.225	
33	0.0199	0.250	
34	0.0186	0.275	
35	0.0180	0.300	
36	0.0190	0.325	
37	0.0192	0.350	
38	0.0190	0.375	
39	0.0189	0.400	
40	0.0188	0.425	
41	0.0195	0.450	
42	0.0200	0.475	
43	0.0200	0.500	
44	0.0190	0.525	
45	0.0200	0.550	
46	0.0205	0.600	
47	0.0210	0.650	
48	0.0202	0.700	
49	0.0205	0.750	
50	0.0208	0.800	
51	0.0180	0.850	
52	0.0180	0.875	
53	0.0160	0.900	
54	0.0170	0.925	400.0

T/C No.	b, in.	X/L	Z_o
55	0.0220	0.950	400.0
56	0.0170	0.300	372.5
57	0.0170	0.325	
58	0.0170	0.350	
59	0.0170	0.375	
60	0.0170	0.400	
61	0.0170	0.425	
62	0.0172	0.450	
63	0.0175	0.475	
64	0.0180	0.500	
65	0.0180	0.525	
66	0.0190	0.550	
67	0.0198	0.600	
68	0.0190	0.650	
69	0.0200	0.700	
70	0.0200	0.750	372.5
71	0.0195	0.200	355.0
72	0.0190	0.225	
73	0.0190	0.250	
74	0.0180	0.275	
75	0.0185	0.800	
76	0.0188	0.850	
77	0.0170	0.875	
78	0.0172	0.900	
79	0.0180	0.925	
80	0.0190	0.950	355.0

TABLE 4 83-Ø MODEL THERMOCOUPLE LOCATIONS

T/C NO.	LOCATION	Z_o (INCHES)	X_o (INCHES)	X/ L	r (INCHES)	θ (DEGREES)	SKIN THICKNESS (INCHES)	
	UPPER RCS NOZZLES							
161	↓	-7.5	315.0	0.0619			0.0265	
162		-7.5	326.7	0.0709			0.0212	
163		-7.5	339.3	0.0807			0.0275	
164		-7.5	357.0	0.0943			0.0292	
165		-7.5	361.5	0.0978			0.0282	
166		-7.5	366.0	0.1013			0.0287	
167		-15.0	315.0	0.0619			0.0303	
168		-15.0	326.7	0.0709			0.0235	
169		-15.0	339.3	0.0807			0.0272	
170		-15.0	357.0	0.0943			0.0280	
171		-15.0	361.5	0.0978			0.0270	
172		-15.0	366.0	0.1013			0.0292	
173		-22.5	339.3	0.0807			0.0299	
174		-22.5	357.0	0.0943			0.0255	
175		-22.5	361.5	0.0978			0.0321	
176		-22.5	366.0	0.1013			0.0305	

TABLE 4 Continued

T/C NO.	LOCATION	RAY	LINE	SKIN THICKNESS (INCHES)	
177	CANOPY	1	4	0.0308	
178		1	6	0.0440	
179		2	6	0.0469	
180		3	3	0.0292	
181		3	4	0.0304	
182		3	5	0.0319	
183		4	1	0.0281	
184			2	0.0306	
185			3	0.0269	
186			4	0.0281	
187			5	0.0298	
188			6	0.0592	
189		5	3	0.0319	
190		5	4	0.0322	
191		5	5	0.0342	
192		6	2	0.0316	
193		6	6	0.0431	
194		7	3	0.0289	
195		7	4	0.0276	
196		7	5	0.0294	
197		8	1	0.0222	
198			2	0.0260	
199			3	0.0301	
200			4	0.0319	

TABLE 4 Continued

T/C NO.	LOCATION	RAY	LINE	SKIN THICKNESS (INCHES)	
201	CANOPY	8	5	0.0316	
202		8	6	0.0283	
203		9	3	0.0278	
204		9	4	0.0348	
205		9	5	0.0349	
206		10	2	0.0297	
207		10	6	0.0300	
208		11	3	0.0301	
209		11	4	0.0308	
210		11	5	0.0299	
211		12	1	0.0272	
212			2	0.0302	
213			3	0.0297	
214			4	0.0314	
215			5	0.0318	
216			6	0.0318	
217			7	0.0319	
218		13	3	0.0309	
219			4	0.0315	
220			5	0.0308	
221		14	1	0.0271	
222			2	0.0276	
223			6	0.0304	

TABLE

TABLE 4 Continued

T/C NO.	LOCATION	Z_o (INCHES)	X_o (INCHES)	X/L	r (INCHES)	θ (DEGREES)	SKIN THICKNESS (INCHES)	
	ESCAPE HATCH & WINDOW							
224		485.0	7.6	0.1933			0.0223	
225		490.0	7.6	0.1972			0.0268	
226		485.0	18.0	0.1933			0.0236	
227		490.0	18.0	0.1972			0.0328	
228		485.0	30.6	0.1933			0.0288	
229		490.0	30.6	0.1972			0.0288	
232		567.0	11.0	0.2567			0.0303	
233		572.0	11.0	0.2606			0.0340	
234		547.5	23.0	0.2416			0.0305	
235		559.5	23.0	0.2509			0.03505	
236		567.0	23.0	0.2567			0.0328	
237		572.0	23.0	0.2606			0.0315	
	CARGO BAY HINGES - HINGE NO. 1							
238		607.3	420.0	0.2879			0.030	
239		612.3	420.0	0.2917			0.030	
240		602.3	415.0	0.2840			0.032	
241		607.3	415.0	0.2879			0.0315	
242		612.3	415.0	0.2917			0.032	
243		597.3	405.0	0.2801			0.0274	
244		602.3	405.0	0.2840			0.0262	
	HINGE NO. 2							
245		674.8	420.0	0.3192			0.032	
246		679.8	420.0	0.3439			0.032	
247		669.8	415.0	0.3362			0.033	
248		674.8	415.0	0.3401			0.033	
249		679.8	415.0	0.3439			0.033	

TABLE 4 Continued

T/C NO.	LOCATION	Z_o (INCHES)	X_o (INCHES)	X/L	r (INCHES)	θ (DEGREES)	SKIN THICKNESS (INCHES)	
	CARGO BAY HINGES - HINGE NO. 2							
250		664.8	405.0	0.3323			0.0281	
251		669.8	405.0	0.3362			0.0275	
	HINGE NO. 3							
252		742.3	420.0	0.3923			0.0325	
253		747.3	420.0	0.3961			0.0325	
254		737.3	415.0	0.3884			0.034	
257		732.3	405.0	0.3845			0.0302	
258		737.3	405.0	0.3884			0.0305	

TABLE 4 Continued

T/C No.	Z_o	X_o	X/L	Skin Thickness
BOTTOM CENTERLINE				
273		236.25	0.0010	0.0269
274		237.37	0.0018	0.0272
275		240.25	0.0041	0.0277
276		244.00	0.0070	0.0280
277		248.28	0.0103	0.0279
278		254.40	0.0150	0.0283
279		260.75	0.0199	0.0232
280		265.00	0.0232	0.0210
281		269.00	0.0263	0.0190
282		273.63	0.0299	0.0230
283		278.75	0.0338	0.0231
284		284.25	0.0381	0.0230
285		288.50	0.0414	0.0230
286		293.5	0.0452	0.0240
287		300.00	0.0503	0.0230
288		364.330	0.100	0.0280
289		428.995	0.150	0.0300
290		493.660	0.200	0.0260
291		558.325	0.250	0.0273
292		622.990	0.300	0.0275
293		687.655	0.350	0.0261
294		752.320	0.400	0.0276
295		816.985	0.450	0.0292
MHB LINE				
296		267.333	0.025	0.0292
297		299.665	0.050	0.0268
298		331.998	0.075	0.0270
299		364.330	0.100	0.0278

T/C No.	Z_o	X_o	X/L	Skin Thickness
MHB LINE				
300		396.663	0.125	0.0252
301		428.995	0.150	0.0280
302		461.3275	0.175	0.0306
303		493.660	0.200	0.0280
304		525.993	0.225	0.0205
305		558.325	0.250	0.0283
306		590.658	0.275	0.0340
307		655.323	0.325	0.0245
308		719.988	0.375	0.0290
309		784.318	0.425	0.0298
310		849.318	0.475	0.0272
311	355.0	493.66	0.200	0.0230
312		525.993	0.225	0.0250
313		558.325	0.250	0.0296
314		590.658	0.275	0.0279
315		622.990	0.300	0.0308
316		655.323	0.325	0.0279
317		687.655	0.350	0.0311
318		719.988	0.375	0.0302
319		752.320	0.400	0.0278
320		784.653	0.425	0.0285
321		816.985	0.450	0.0276
322	355.0	849.318	0.475	0.0260
323	378.0	493.660	0.200	0.0259
324		525.993	0.225	0.0268
325		558.325	0.250	0.0279
326		590.658	0.275	0.0261
327		622.990	0.300	0.0286
328		655.323	0.325	0.0249
329		687.655	0.350	0.0306
330		719.988	0.375	0.0282
331		752.320	0.400	0.0269
332		784.653	0.425	0.0276
333	378.0	816.985	0.450	0.0273
334	400.0	525.993	0.225	0.0255
335		558.325	0.250	0.0289
336		590.658	0.275	0.0262
337		622.990	0.300	0.0308
338		655.323	0.325	0.0269
339		687.655	0.350	0.0302

TABLE 4 Continued

T/C No.	Z_o	X_o	X/L	Skin Thickness
MHB LINE (CONT'D)				
340	400.0	719.988	0.375	0.0300
341		752.320	0.400	0.0279
342		784.653	0.425	0.0270
343	400.0	816.985	0.450	0.0276
344	425.0	655.335	0.325	0.031
345		687.655	0.350	0.030
346		719.988	0.375	0.030
347		752.320	0.400	0.030
348		784.653	0.425	0.032
349		816.985	0.450	0.031
350	425.0	850.600	0.4760	0.033
CCL LINE				
351		299.665	0.050	0.0271
352		331.998	0.075	0.0269
353		364.330	0.100	0.0263
354		396.663	0.125	0.0268
355		428.995	0.150	0.0273
356		461.328	0.175	0.0311
357		493.660	0.200	0.0262
358		590.658	0.275	0.032
359		622.990	0.300	0.0310
360		655.323	0.325	0.030
361		687.655	0.350	0.0305
362		719.988	0.375	0.030
363		752.320	0.400	0.032
364		784.653	0.425	0.032
365		816.985	0.450	0.032
366		850.600	0.4760	0.0315
TOP CENTERLINE				
367		235.000	0.000	0.0263
368		236.000	0.0008	0.0284
369		237.500	0.0019	0.0262
370		239.750	0.0037	0.0273
371		242.500	0.0058	0.0219
372		246.250	0.0087	0.0268
373		250.250	0.0118	0.0293

T/C No.	Z_o	X_o	X/L	Skin Thickness
TOP CENTERLINE (CONT'D)				
374		254.50	0.0151	0.0293
375		258.50	0.0182	0.0306
376		262.75	0.0215	0.0295
377		266.75	0.0246	0.0288
378		271.00	0.0278	0.0261
379		313.75	0.0609	0.0275
380		318.50	0.0646	0.023
381		323.50	0.0684	0.029
382		328.25	0.0721	0.0293
383		333.25	0.0760	0.030
384		338.00	0.0796	0.0312
385		358.00	0.0953	0.0288
386		362.60	0.0989	0.0265
387		366.75	0.1019	0.0275
388		385.00	0.1160	0.0213
389		389.50	0.1195	0.0325
390		394.25	0.1231	0.0353
391		399.00	0.1268	0.0357
392		403.75	0.1305	0.0384
393		408.00	0.1338	0.0379
394		413.00	0.1376	0.0376
395		417.50	0.1411	0.0335
396		422.25	0.1448	0.0332
397		426 75	0.1483	0.0332
398		431.50	0.1519	0.0315
399		436.25	0.1556	0.0299
400		439.63	0.1582	0.0302
401		443.00	0.1608	0.0290
402		446.50	0.1635	0.0279
403		450.25	0.1664	0.0272
404		453.75	0.1691	0.0271
405		457.50	0.1720	0.0271
406		461.00	0.1748	0.0271
407		463.75	0.1769	0.0289
408		466.75	0.1800	0.0328
409		471.75	0.1831	0.0322
410		476.00	0.1863	0.0322
411		480.00	0.1894	0.0336
412		474.75	0.1931	0.0312

TABLE 4 Continued

T/C NO.	LOCATION	Z_o (INCHES)	X_o (INCHES)	X/L	r (INCHES)	θ (DEGREES)	SKIN THICKNESS (INCHES)	
413	TOP CENTERLINE		490.00	0.1972			0.0300	
414			500.00	0.2049			0.0300	
415			525.993	0.2250			0.0221	
416			558.325	0.250			0.0262	
417			590.658	.275			0.0330	
418			622.990	.300			0.0350	
419			655.323	.325			0.0330	
420			687.655	.350			0.0322	
421			719.988	.375			0.0329	
422			752.320	.400			0.0328	
423			784.652	.425			0.0316	
424			816.985	.450			0.0335	
425			849.318	.475			0.034	
426	PILOT RIGHT (Cross Section)		270	.027		350	0.0206	
427						343	0.0219	
428						335	0.0239	
429						324	0.0259	
430						320	0.0279	
431						310	0.0285	
432						303	0.0288	
433						295	0.0288	
434						287.5	0.0292	
435						280	0.0293	
436						273	0.0295	
437			300	.050		352.5	0.025	
438						347	0.0258	
439						339	0.0249	
440						334	0.024	

TABLE 4 Continued

T/C NO.	LOCATION	Z_o (INCHES)	X_o (INCHES)	X/L	r (INCHES)	θ (DEGREES)	SKIN THICKNESS (INCHES)	
441	PILOT RIGHT (Cross Section)		300	.050		327.5	0.024	
442						321.5	0.028	
443						318	0.0283	
444						311	0.0270	
445						306	0.026	
446						300	0.0245	
447						295	0.0225	
448						289	0.0278	
449						284	0.0258	
450						274	0.0190	
451			500	.2049		355	0.025	
452						351	0.023	
453						346	0.023	
454						342	0.023	
455						338	0.023	
456						333	0.023	
457						330	0.023	
458						326	0.024	
459						322	0.026	
460						320	0.026	
461						317	0.027	
462						313.5	0.027	
463						310.5	0.026	
464						307	0.025	
465						305	0.0263	
466						303	0.027	
467						300.5	0.0265	
468						298	0.025	

TABLE 4 Concluded

T/C NO.	LOCATION	Z_o (INCHES)	X_o (INCHES)	X/L	r (INCHES)	θ (DEGREES)	SKIN THICKNESS (INCHES)	
469	PILOT RIGHT (Cross Section)		500	.2049		295	0.028	
470						292	0.023	
471						290	0.023	
472						287	0.021	
473						284	0.0275	
474						278	0.023	
475						275.5	0.023	
476						273	0.024	
477						270	0.0253	
501			260.75	.0200		348.5	0.022	
502						338.2	0.021	
503						328.7	0.025	
504						320.5	0.028	
505						312.3	0.027	
506						303.5	0.025	
507						296.5	0.021	
508						287	0.019	
509						278.6	0.023	
510						270.0	0.023	
511						262	0.026	

TABLE 5. THERMOCOUPLE CONSTANT SETS

CONSTANT SET 111
MODEL: 60-Ø

Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	340	X/C	Z/BV	34	373	X/C	Z/BV	67	320	X_o	Y_o
2	341			35	374			68	321		
3	342			36	375			69	322		
4	343			37	376			70	323		
5	344			38	377			71	325		
6	345			39	378			72	327		
7	346			40	379			73	328		
8	347			41	380			74	329		
9	348			42	381			75	330		
10	349			43	382			76	331		Y_o
11	350			44	383			77	332		Z_o
12	351			45	384			78	333		
13	352			46	385	X/C	Z/BV	79	334		
14	353			47	298	X_o	Y_o	80	335		Z_o
15	354			48	299			81	336		Y_o
16	355			49	300			82	337		Z_o
17	356			50	301			83	338		
18	357			51	302			84	339	X_o	
19	358			52	303			85	368A	X/L	Z_o
20	359			53	304			86	397C	-	-
21	360			54	305			87	398C	-	-
22	361			55	306			88	399C	-	-
23	362			56	308			89	400C	-	-
24	363			57	309			90	110C	X/C	Y_o
25	364			58	310			91	111C		
26	365			59	311			92	112C		
27	366			60	312			93	113C		
28	367			61	313			94	114C		
29	368			62	315			95	115C		
30	369			63	316			96	116C		
31	370			64	317			97	117C	X/C	Y_o
32	371			65	318						
33	372	X/C	Z/BV	66	319	X_o	Y_o				

TABLE 5. Continued

CONSTANT SET 122

MODEL: 60-Ø

Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	1	X/L	ϕ	34	182	X/L	ϕ	67	88A	X/L	Y
2	2			35	223			68	89A		
3	3			36	234			69	103A		
4	4	X/L	ϕ	37	388			70	102A		
5	120	X/C	Y	38	184			71	127A		
6	121			39	225			72	126A		
7	122			40	236			73	125A		
8	123			41	390			74	124A		
9	253			42	186			75	122A		
10	254			43	188			76	140A		
11	255			44	229			77	139A		
12	256			45	240			78	408A		
13	257			46	394			79	407A		
14	258			47	190			80	406A		
15	259			48	231			81	405A		
16	260			49	242		ϕ	82	404A		
17	261	X/C	Y	50	279A		Y	83	410A		
18	460	2Y/B	X_o	51	249A			84	156A		
19	461			52	250A			85	155A		
20	462			53	251A			86	36A		
21	463			54	252A			87	160A		
22	464			55	253A			88	159A		
23	465			56	254A			89	158A		
24	466			57	255A			90	157A		Y
25	467			58	256A			91	320A		Z
26	468			59	257A			92	321A		
27	469			60	258A			93	322A		
28	470			61	259A			94	323A	X/L	Z
29	471			62	260A			95	118C	X/C	Y
30	274			63	261A			96	119C	X/C	Y
31	472			64	262A			97	288C	X/L	Z
32	277			65	263A						
33	473	2Y/B	X_o	66	87A	X/L	Y				

TABLE 5. Continued

CONSTANT SET 133
MODEL: 60-Ø

Ch No	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	5	X/L	φ	34	218	X/L	Z	67	70A	X/L	Y
2	6		φ	35	219		Z	68	107A		
3	7		φ	36	23		φ	69	114A		
4	44		Y	37	24			70	115A		
5	202		Z	38	25			71	116A		
6	203			39	26	X/L	φ	72	117A		
7	204			40	191	Y	Z	73	118A		
8	205		Z	41	192			74	130A		
9	8		φ	42	193			75	131A		
10	206		Z	43	194			76	132A		
11	9		φ	44	195			77	133A		
12	10			45	196			78	134A		
13	11			46	197			79	135A		Y
14	12		φ	47	198			80	220C		Z
15	45		Y	48	199			81	27C		φ
16	207		Y	49	200			82	28C		φ
17	208		Y	50	201	Y	Z	83	50C		Y
18	209		Z	51	164	X/C	Y	84	62C		Y
19	13		φ	52	165			85	29C		φ
20	14			53	166			86	30C		φ
21	15			54	167			87	51C		Y
22	16		φ	55	168	X/C	Y	88	63C		Y
23	211		Y	56	18	X/L	φ	89	31C		φ
24	212			57	278	X/C	Y	90	32C		φ
25	213			58	279	X/C		91	52C		Y
26	214		Y	59	280	X/C		92	64C		Y
27	21		φ	60	37A	X/L		93	33C		φ
28	17		φ	61	38A		Y	94	34C		φ
29	48		Y	62	39A		Z	95	53C		Y
30	19		φ	63	45A		Y	96	65C		Y
31	215		Y	64	46A		Z	97	35C	X/L	φ
32	216		Y	65	47A		Y				
33	217	X/L	Y	66	65A	X/L	Y				

TABLE 5. Continued

CONSTANT SET 211
MODEL: 60-Ø

Ch No	TC No.	COORD1	COORD2	Ch No	TC No.	COORD1	COORD2	Ch No	TC No.	COORD1	COORD2
1	432	XN	ϕ_N	34	60	X/L	Y_O	67	188A	X/L	Y_O
2	433			35	69			68	189A		Y_O
3	434			36	70			69	196A		Y_O
4	435			37	71			70	320A		Z_O
5	436			38	72	X/L		71	321A		
6	437			39	164	X/C		72	322A		
7	438			40	165			73	323A		
8	439			41	166			74	336A		
9	440			42	167			75	337A		
10	441			43	168			76	338A		
11	442			44	156			77	339A		
12	443			45	158			78	341A		
13	444			46	159			79	342A		
14	445			47	146			80	343A		
15	446			48	147			81	344A		Z_O
16	447			49	148			82	34C		ϕ
17	448			50	138			83	35C		
18	449			51	139			84	36C		
19	450			52	140			85	37C		
20	451			53	142	X/C		86	38C		
21	452			54	314A	X/L		87	39C		ϕ
22	453	XN	ϕ_N	55	315A			88	54C		Y_O
23	428	Y_O	Z_O	56	316A			89	55C		
24	429			57	317A			90	5 C		
25	430			58	318A			91	66C		
26	431	Y_O	Z_O	59	319A			92	67C		
27	40	X/L	ϕ	60	113A			93	68C		Y_O
28	41			61	191A		Y_O	94	288C	X/L	Z_O
29	42			62	192A		Z_O	95	155C	X/C	Y_O
30	43		ϕ	63	193A		Z_O	96	157C	X/C	Y_O
31	57		Y_O	64	194A		Z_O	97	141C	X/C	Y_O
32	58		Y_O	65	186A		Y_O				
33	59	X/L	Y_O	66	187A	X/L	Y_O				

TABLE 5. Continued

CONSTANT SET 222
MODEL: 60-Ø

Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	143	X/C	Y_o	34	464	2Y/B	X_o	67	491	2Y/B	X/C
2	144			35	264	X/C	Y_o	68	472	2Y/B	X_o
3	131			36	465	2Y/B	X_o	69	275	X/C	Y_o
4	132			37	265	X/C	Y_o	70	276	X/C	Y_o
5	120			38	266	X/C	Y_o	71	277	2Y/B	X_o
6	121			39	267	X/C	Y_o	72	278	X/C	Y_o
7	122			40	477	2Y/B	X_o	73	279	X/C	Y_o
8	123			41	268	X/C	Y_o	74	280	X/C	Y_o
9	107			42	466	2Y/B	X_o	75	473	2Y/B	X_o
10	95			43	269	X/C	Y_o	76	253	X/C	Y_o
11	96			44	270	X/C	Y_o	77	254	X/C	
12	97			45	467	2Y/B	X_o	78	255	X/C	
13	83			46	478		X/C	79	197A	X/L	
14	84			47	479			80	279A	X/L	
15	247			48	480			81	130C	X/C	
16	248			49	481		X/C	82	116C		
17	249			50	468		X_o	83	117C		
18	250			51	482	2Y/B	X	84	118C		
19	251			52	271	X/C	Y_o	85	119C		
20	252	X/C	Y_o	53	469	2Y/B	X_o	86	104C		
21	460	2Y/B	X_o	54	483		X	87	105C		
22	461	2Y/B	X_o	55	484		X/C	88	106C		
23	256	X/C	Y_o	56	485			89	92C		
24	257			57	486			90	93C		
25	258			58	487			91	94C		
26	259	X/C	Y_o	59	488			92	78C		
27	462	2Y/B	X_o	60	489		X/C	93	79C		
28	260	X/C	Y_o	61	470		X_o	94	80C		
29	261	X/C	Y_o	62	490		X	95	81C		
30	463	2Y/B	X_o	63	471	2Y/B	X_o	96	82C	X/C	Y_o
31	262	X/C	Y_o	64	272	X/C	Y_o	97			
32	263	X/C	Y_o	65	273	X/C	Y_o				
33	476	2Y/B	X/C	66	274	2Y/B	X_o				

TABLE 5. Continued

CONSTANT SET 311
MODEL: 56-Ø

Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	1	X/L	Z	34	34	X/L	Z	67	67	X/L	Z
2	2			35	35			68	68		
3	3			36	36			69	69		
4	4			37	37			70	70		
5	5			38	38			71	71		
6	6			39	39			72	72		
7	7			40	40			73	73		
8	8			41	41			74	74		
9	9			42	42			75	75		
10	10			43	43			76	76		
11	11			44	44			77	77		
12	12			45	45			78	78		
13	13			46	46			79	79		
14	14			47	47			80	80	X/L	Z
15	15			48	48			81			
16	16			49	49			82			
17	17			50	50			83			
18	18			51	51			84			
19	19			52	52			85			
20	20			53	53			86			
21	21			54	54			87			
22	22			55	55			88			
23	23			56	56			89			
24	24			57	57			90			
25	25			58	58			91			
26	26			59	59			92			
27	27			60	60			93			
28	28			61	61			94			
29	29			62	62			95			
30	30			63	63			96			
31	31			64	64			97			
32	32			65	65						
33	33	X/L	Z	66	66	X/L	Z				

TABLE 5. Continued

CONSTANT SET 411
MODEL: 83-Ø

Ch No	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	273	X/L	Φ	34	307	X/L	Z	67	345	X/L	Z
2	274			35	308			68	346		
3	275			36	309			69	347		
4	276			37	311			70	348		
5	277			38	312			71	351		
6	278			39	313			72	352		
7	279			40	314			73	353		
8	280			41	315			74	354		
9	281			42	316			75	355		
10	282			43	317			76	356		
11	283			44	318			77	357		
12	284			45	319			78	358		
13	285			46	320			79	359		
14	286			47	323			80	360		
15	287			48	324			81	361		
16	288			49	325			82	362		
17	289			50	326			83	363		
18	290			51	327			84	364		Z
19	291			52	328			85	427		Φ
20	292			53	329			86	428		
21	293			54	330			87	429		
22	294		Φ	55	331			88	430		
23	296		Z	56	332			89	431		
24	297			57	334			90	432		
25	298			58	335			91	433		
26	299			59	336			92	434		
27	300			60	337			93	435		
28	301			61	338			94	436		
29	302			62	339			95	437		
30	303			63	340			96	438	X/L	Φ
31	304			64	341			97			
32	305			65	342						
33	306	X/L	Z	66	344	X/L	Z				

TABLE 5. Continued

CONSTANT SET 422
MODEL: 83-Ø

Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	439	X/L	ϕ	34	472	X/L	ϕ	67	394	X/L	ϕ
2	440			35	473			68	395		
3	441			36	474			69	396		
4	442			37	475			70	397		
5	443			38	476			71	398		
6	444			39	477			72	399		
7	445			40	367			73	400		
8	446			41	368			74	401		
9	447			42	369			75	402		
10	448			43	370			76	403		
11	449			44	371			77	404		
12	450			45	372			78	405		
13	451			46	373			79	406		
14	452			47	374			80	407		
15	453			48	375			81	408		
16	454			49	376			82	409		
17	455			50	377			83	410		
18	456			51	378			84	411		
19	457			52	379			85	412		
20	458			53	380			86	413		
21	459			54	381			87	414		
22	460			55	382			88	415		
23	461			56	383			89	416		
24	462			57	384			90	417		
25	463			58	385			91	418		
26	464			59	386			92	419		
27	465			60	387			93	420		
28	466			61	388			94	421		
29	467			62	389			95	422		
30	468			63	390			96	423	X/L	ϕ
31	469			64	391			97			
32	470			65	392						
33	471	X/L	ϕ	66	393	X/L	ϕ				

TABLE 5. Continued

CONSTANT SET 511
MODEL: 60-Ø

Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	340	X/C	Z/BV	34	373	X/C	Z/BV	67	320	X_o	Y_o
2	341			35	374			68	321		
3	342			36	375			69	322		
4	343			37	376			70	323		
5	344			38	377			71	325		
6	345			39	378			72	327		
7	346			40	379			73	328		
8	347			41	380			74	329		
9	348			42	381			75	330		
10	349			43	382			76	331		Y_o
11	350			44	383			77	332		Z_o
12	351			45	384			78	333		Z_o
13	352			46	385	X/C	Z/BV	79	334		Z_o
14	353			47	298	X_o	Y_o	80	336		Y_o
15	354			48	299			81	337		Z_o
16	355			49	300			82	338		Z_o
17	356			50	301			83	339	X_o	Z_o
18	357			51	302			84	249A	X/L	Y_o
19	358			52	303			85	250A		
20	359			53	304			86	251A		
21	360			54	305			87	252A		
22	361			55	306			88	253A		
23	362			56	308			89	254A		
24	363			57	309			90	255A		
25	364			58	310			91	256A		
26	365			59	311			92	257A		
27	366			60	312			93	258A		
28	367			61	313			94	259A		
29	368			62	315			95	260A		Y_o
30	369			63	316			96	368A	X/L	Z_o
31	370			64	317			97			
32	371			65	318						
33	372	X/C	Z/BV	66	319	X_o	Y_o				

TABLE 5. Continued

CONSTANT SET 522
MODEL: 60-Ø

Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	4	X/L	ϕ	34	268	X/C	Y_o	67	280	X/C	Y_o
2	7	X/L	ϕ	35	466	2Y/B	X_o	68	473	2Y/B	X_o
3	227	X/L	ϕ	36	269	X/C	Y_o	69	169	X/L	ϕ
4	246	X/C	Y	37	270	X/C	Y_o	70	170		
5	247			38	467	2Y/B	X_o	71	171		
6	248			39	478		X/C	72	172		
7	249			40	479			73	173		
8	250			41	480			74	174		
9	251			42	481		X/C	75	175		
10	252	X/C	Y	43	468		X_o	76	176		
11	460	2Y/B	X_o	44	482	2Y/B	X/C	77	177		
12	461	2Y/B	X_o	45	271	X/C	Y_o	78	178		
13	253	X/C	Y_o	46	469	2Y/B	X_o	79	179		
14	254			47	483		X/C	80	182		
15	255			48	484			81	183		
16	256			49	485			82	184		
17	257			50	486			83	185		
18	258			51	487			84	186		
19	259	X/C	Y_o	52	488			85	187		
20	462	2Y/B	X_o	53	489		X/C	86	188		
21	260	X/C	Y_o	54	470		X_o	87	189		
22	261	X/C	Y_o	55	490		X_o	88	190		ϕ
23	463	2Y/B	X_o	56	471	2Y/B	X_o	89	87A		Y_o
24	262	X/C	Y_o	57	272	X/C	Y_o	90	88A		
25	263	X/C	Y_o	58	273	X/C	Y_o	91	89A		
26	476	2Y/B	X/C	59	274	X/C	Y_o	92	103A		
27	464	2Y/B	X/C	60	491	2Y/B	X/C	93	102A		
28	264	X/C	Y_o	61	472	2Y/B	X_o	94	261A		
29	465	2Y/B	X/C	62	275	X/C	Y_o	95	262A		
30	265	X/C	Y_o	63	276			96	263A	X/L	Y_o
31	266	X/C	Y_o	64	277			97			
32	267	X/C	Y_o	65	278						
33	477	2Y/B	X/C	66	279	X/C	Y_o				

TABLE 5. Continued

CONSTANT SET 533
MODEL: 60-Ø

Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	223	X/L	ϕ	34	198	Y_o	Z_o	67	404A	X/L	Y_o
2	234		ϕ	35	199			68	410A		
3	388		Z_o	36	200			69	156A		
4	224		ϕ	37	201	Y_o		70	155A		
5	235		ϕ	38	202	X/L		71	36A		
6	389		Z_o	39	203			72	160A		
7	225		ϕ	40	204			73	159A		
8	236		ϕ	41	205			74	158A		
9	390		Z_o	42	206		Z_o	75	157A		Y_o
10	226		ϕ	43	207		Y_o	76	320A		Z_o
11	237		ϕ	44	208		Y_o	77	321A		
12	391		Z_o	45	209		Z_o	78	322A		
13	238		ϕ	46	210		Z_o	79	323A		
14	392		Z_o	47	211		Y_o	80	336A		
15	228		ϕ	48	212			81	337A		
16	239		ϕ	49	213			82	338A		
17	393		Z_o	50	214			83	339A		
18	229		ϕ	51	215			84	341A		
19	240		ϕ	52	216			85	342A		
20	394		Z_o	53	217		Y_o	86	343A		
21	230		ϕ	54	218		Z_o	87	344A		Z_o
22	241		ϕ	55	219		Z_o	88	37A		Y_o
23	395		Z_o	56	127A		Y_o	89	38A		Y_o
24	231		ϕ	57	126A			90	39A		Z_o
25	242		ϕ	58	125A			91	45A		Y_o
26	396	X/L	Z_o	59	124A			92	46A		Z_o
27	191	Y_o	Z_o	60	122A			93	47A		Y_o
28	192			61	140A			94	70A		Y_o
29	193			62	139A			95	220C		Z_o
30	194			63	408A			96	288C	X/L	Z_o
31	195			64	407A			97			
32	196			65	406A						
33	197	Y_o	Z_o	66	405A	X/L	Y_o				

TABLE 5. Continued

CONSTANT SET 711
MODEL: 60-Ø

Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	340	X/C	Z/BV	34	373	X/C	Z/BV	67	320	X_o	Y_o
2	341			35	374			68	321		
3	342			36	375			69	322		
4	343			37	376			70	323		
5	344			38	377			71	325		
6	345			39	378			72	327		
7	346			40	379			73	328		
8	347			41	380			74	329		
9	348			42	381			75	330		
10	349			43	382			76	331		Y_o
11	350			44	383			77	332		Z_o
12	351			45	384			78	333		
13	352			46	385	X/C	Z/BV	79	334		
14	353			47	298	X_o	Y_o	80	335		Z_o
15	354			48	299			81	336		Y_o
16	355			49	300			82	337		Z_o
17	356			50	301			83	338		
18	357			51	302			84	339	X_o	
19	358			52	303			85	368A	X/L	Z_o
20	359			53	304			86	397C	-	-
21	360			54	305			87	398C	-	-
22	361			55	306			88	399C	-	-
23	362			56	308			89	400C	-	-
24	363			57	309			90	110C	X/C	Y_o
25	364			58	310			91	111C		
26	365			59	311			92	112C		
27	366			60	312			93	113C		
28	367			61	313			94	114C		
29	368			62	315			95	115C		
30	369			63	316			96	116C		
31	370			64	317			97	117C	X/C	Y_o
32	371			65	318						
33	372	X/C	Z/BV	66	319	X_o	Y_o				

TABLE 5. Continued

CONSTANT SET **722**
MODEL: 60-Ø

Ch No	TC No.	COORD1	COORD2	Ch No	TC No.	COORD1	COORD2	Ch No	TC No.	COORD1	COORD2
1	1	X/L	φ	34	182	X/L	φ	67	88A	X/L	Y
2	2			35	223			68	89A		
3	3			36	234			69	103A		
4	4	X/L	φ	37	388			70	102A		
5	120	X/C	Y	38	184			71	127A		
6	121			39	225			72	126A		
7	122			40	236			73	125A		
8	123			41	390			74	124A		
9	253			42	186			75	122A		
10	254			43	188			76	140A		
11	255			44	229			77	139A		
12	256			45	240			78	408A		
13	257			46	394			79	407A		
14	258			47	190			80	406A		
15	259			48	231			81	405A		
16	260			49	242		φ	82	404A		
17	261	X/C	Y	50	279A		Y	83	410A		
18	460	2Y/B	X_o	51	249A			84	156A		
19	461			52	250A			85	155A		
20	462			53	251A			86	36A		
21	463			54	252A			87	160A		
22	464			55	253A			88	159A		
23	465			56	254A			89	158A		
24	466			57	255A			90	157A		Y
25	467			58	256A			91	320A		Z
26	468			59	257A			92	321A		
27	469			60	258A			93	322A		
28	470			61	259A			94	323A	X/L	Z
29	471			62	260A			95	118C	X/C	Y
30	274			63	261A			96	119C	X/C	Y
31	472			64	262A			97	288C	X/L	Z
32	277			65	263A						
33	473	2Y/B	X_o	66	87A	X/L	Y				

TABLE 5. Continued

CONSTANT SET 733

MODEL: 60-Ø

Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	5	X/L	Φ	34	218	X/L	Z	67	70A	X/L	Y
2	6		Φ	35	219		Z	68	107A		
3	7		Φ	36	23		Φ	69	114A		
4	44		Y	37	24			70	115A		
5	202		Z	38	25			71	116A		
6	203			39	26	X/L	Φ	72	117A		
7	204			40	191	Y	Z	73	118A		
8	205		Z	41	192			74	130A		
9	8		Φ	42	193			75	131A		
10	206		Z	43	194			76	132A		
11	9		Φ	44	195			77	133A		
12	10			45	196			78	134A		
13	11			46	197			79	135A		Y
14	12		Φ	47	198			80	220C		Z
15	45		Y	48	199			81	27C		Φ
16	207		Y	49	200			82	28C		Φ
17	208		Y	50	201	Y	Z	83	50C		Y
18	209		Z	51	164	X/C	Y	84	62C		Y
19	13		Φ	52	165			85	29C		Φ
20	14			53	166			86	30C		Φ
21	15			54	167			87	51C		Y
22	16		Φ	55	168	X/C	Y	88	63C		Y
23	211		Y	56	18	X/L	Φ	89	31C		Φ
24	212			57	278	X/C	Y	90	32C		Φ
25	213			58	279	X/C		91	52C		Y
26	214		Y	59	280	X/C		92	64C		Y
27	21		Φ	60	37A	X/L		93	33C		Φ
28	17		Φ	61	38A		Y	94	34C		Φ
29	48		Y	62	39A		Z	95	53C		Y
30	19		Φ	63	45A		Y	96	65C		Y
31	215		Y	64	46A		Z	97	35C	X/L	Φ
32	216		Y	65	47A		Y				
33	217	X/L	Y	66	65A	X/L	Y				

TABLE 5. Continued

CONSTANT SET 811
MODEL: 60-Ø

Ch No	TC No.	COORD1	COORD2	Ch No	TC No.	COORD1	COORD2	Ch No	TC No.	COORD1	COORD2
1	276	X/C	Y_o	34	132	X/C	Y_o	67	191A	X/L	Y_o
2	40	X/L	ϕ	35	139			68	192A		Z_o
3	41			36	140			69	193A		Z_o
4	42			37	142			70	194A		Z_o
5	43		ϕ_o	38	143			71	22C		ϕ
6	57		Y_o	39	144			72	36C		
7	58			40	147			73	37C		
8	59			41	148			74	38C		
9	60			42	150			75	39C		ϕ
10	69			43	151			76	54C		Y_o
11	70			44	152			77	55C		
12	71			45	153			78	56C		
13	72		Y_o	46	154			79	66C		
14	20	X/L	ϕ	47	156			80	67C		
15	251	X/C	Y_o	48	158			81	68C	X/L	
16	252			49	159			82	77C	X/C	
17	264			50	162			83	78C		
18	269			51	163	X/C	Y_o	84	79C		
19	270	X/C	Y_o	52	41A	X/L	Z_o	85	80C		
20	482	2Y/B	X_o	53	186A		Y_o	86	81C		
21	271	X/C	Y_o	54	187A			87	82C		
22	483	2Y/B	X_o	55	188A			88	90C		
23	484		X/C	56	189A			89	91C		
24	485		X/C	57	196A		Y_o	90	92C		
25	490		X_o	58	336A		Z_o	91	93C		
26	491	2Y/B	X/C	59	337A			92	94C		
27	83	X/C	Y_o	60	338A			93	105C		
28	84			61	339A			94	106C		
29	95			62	341A			95	141C		
30	96			63	342A			96	155C		
31	97			64	343A			97	157C	X/C	Y_o
32	107			65	344A		Z_o				
33	131	X/C	Y_o	66	113A	X/L	Y_o				

TABLE 5. Continued

CONSTANT SET 911
MODEL: 83-Ø

Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2	Ch No.	TC No.	COORD1	COORD2
1	177	RAY	LINE	34	210	RAY	LINE	67	166	X/L	Z_o
2	178			35	211			68	167		
3	179			36	212			69	168		
4	180			37	213			70	169		
5	181			38	214			71	170		
6	182			39	215			72	171		
7	183			40	216			73	172		
8	184			41	217			74	173		
9	185			42	218			75	174		
10	186			43	219			76	175		
11	187			44	220			77	176		Z_o
12	188			45	221			78	379		ϕ
13	189			46	222			79	380		
14	190			47	223	RAY	LINE	80	381		
15	191			48	224	X/L	Y_o	81	382		
16	192			49	225			82	383		
17	193			50	226			83	384		
18	194			51	227			84	385		
19	195			52	228			85	386		
20	196			53	229			86	387		
21	197			54	230			87	388		
22	198			55	231			88	389		
23	199			56	232			89	390		
24	200			57	233			90	391		
25	201			58	234			91	392		
26	202			59	235			92	393		
27	203			60	236			93	394		
28	204			61	237		Y_o	94	395		
29	205			62	161		Z_o	95	396		
30	206			63	162			96	397		
31	207			64	163			97	398	X/L	ϕ
32	208			65	164						
33	209	RAY	LINE	66	165	X/L	Z_o				

TABLE 5. Concluded

CONSTANT SET 922
MODEL: 83-0

Ch No	TC No.	COORD1	COORD2	Ch No	TC No.	COORD1	COORD2	Ch No	TC No.	COORD1	COORD2
1	399	X/L	Φ	34	288	X/L	Φ	67	451	X/L	Φ
2	400			35	289			68	452		
3	401			36	290			69	453		
4	402			37	291			70	454		
5	403			38	292			71	455		
6	404			39	293			72	456		
7	405			40	294			73	457		
8	406			41	426			74	458		
9	407			42	427			75	459		
10	408			43	428			76	460		
11	409			44	429			77	461		
12	410			45	430			78	462		
13	411			46	431			79	463		
14	412			47	432			80	464		
15	413			48	433			81	465		
16	414			49	434			82	466		
17	415			50	435			83	467		
18	416			51	436			84	468		
19	273			52	437			85	469		
20	274			53	438			86	470		
21	275			54	439			87	471		
22	276			55	440			88	472		
23	277			56	441			89	473		Φ
24	278			57	442			90	303		–
25	279			58	443			91	474		Φ
26	280			59	444			92	475		Φ
27	281			60	445			93	476		Φ
28	282			61	446			94	296		–
29	283			62	447			95	298		
30	284			63	448			96	299		
31	285			64	449		Φ	97	300	X/L	–
32	286			65	297		–				
33	287	X/L	Φ	66	450	X/L	Φ				

TABLE 6. TEST DATA SUMMARY

A. Rockwell Test OH-84B
Model: 60-Ø with base sting
Nominal Mach No.: 8.0

				RE/FT X 10^{-6}	0.5			1.0			2.0			3.0			3.7		
				CONSTANT SET	111	122	133	111	122	133	111	122	133	111	122	133	111	122	133
ALPHA, DEG	YAW, DEG	DELTAE, DEG	DELTBF, DEG	DELTASB, DEG	DATA GROUP NUMBERS														
25	0	0	0	49				9			8			7			6		5
30	0	0	0	0	10	11	12				47	48	49,148	76	77	78	119	120	121
	1										149	150	151	110	111	112	122	123	125
	2										152	153	154	113	114	115	126	127	128
	4										155		157	116	117	118	129	130	131
	-1										50	51	52						
	-2										53,54	55	56						
	-4																		
35	0				13	14	15				60	61	62	79	80	81	132	133	134
	1										158	159	160	101	102	103	135	136	137
	2										161	162	163	104	105	106	138	139	140
	4										164	165	166	107	108	109	141	142	143
40	0				16	17	18	32	33	34	73	74	75	82	83	84	145	146	147
	1				191,192	193	194	179	180	181	167	168	169	85	86	88			
	2				195	196	197	182	183	184	173	174	175	89	90	93			
	4				198	199	200	185	186	187	176	177	178	97	95	96			
	10				201	202	203	188	189	190	170	171	172	98	99	100			
	-1				20	21	22	35	36	37	70	71	72						
	-2				23	24	25	38	39	40	67	68	69						
	-4				26	27	28	41	42	43	63	66	65						
	-10				29	30	31	44	45	46	57	58	59						
40.2	0	0	0	0												87			

NOTE: No data recorded on groups 1, 2, 3, 4, 19, 64, 91, 92, 94, 124, 144, 156

TABLE 6. Continued

B. Rockwell Test OH-84B

Model: 60-Ø with offset sting

Nominal Mach No.: 8.0

				RE/FT X 10^{-6}	0.5		1.0		2.0		3.0	
				CONSTANT SET	211	222	211	222	211	222	211	222
ALPHA, DEG	YAW, DEG	DELTAE, DEG	DELTBF, DEG	DELTASB, DEG	DATA GROUP NUMBERS							
40	0	0	-12.5	0	631	632	605	606	603	604	581	582
			- 5		621	622	615	616	593	594	579	580
			0		623	624	613	614	595	596	577	578
			5		625	626	611	612	597	598	583	584
			8		619	620	617	618	591	592	589	590
			15		627	628	609	610	599	600	585	586
			23.5		629	630	607	608	601	602	587	588
		5	- 5		681	682	667	668	687	688	701	702
			0		679	680	665	666	689	690	699	700
			8		683	684	669	670	685	686	703	704
			15		675	676	673	674	691	692	697	698
			23.5		677	678	671	672	693	694	695	696
		7.5	0		767	768	757	758	755	756	745	746
			15		765	766	759	760	753	754	747	748
			23.5		763	764	761	762	751	752	749	750
		-5	-12.5		633	634	659	660	647	648	649	650
			- 5		635	636	657	658	645	646	655	656
			0		637	638	663	664	643	644	653	654
			5		639	640	661	662	641	642	651	652
		-12.5	-12.5		725	726	739	740	737	738	727	728
			- 5		723	724	741	742	735	736	729	730
			0		721	722	743	744	733	734	731	732
		-15	-12.5		717	718	715	716	709	710	707	708
			0		719	720	713	714	711	712	705	706

TABLE 6. Continued

C. Rockwell Test OH-105

Model: 60-Ø

Nominal Mach No.: 8.0

ALPHA, DEG	YAW, DEG	DELTAE, DEG	DELTBF, DEG	DELTASB, DEG	RE/FT X 10^{-6}, 1/FT: 1.0				3.0				3.7			
				CONSTANT SET	711	722	733	811	711	722	733	811	711	722	733	811
					DATA GROUP NUMBERS											
0	0	0	0	0	204	205	206	382	216	217	218	378	228	229	230	373 377
10	↓	↓	↓	↓	207	208	209	383	219	220	221	379	231	232	233	374
15	↓	↓	↓	↓	210	211	212	384	222	223	224	380	237	238	239	375
20	↓	↓	↓	↓	213	215	214	385	225	226	227	381	234	235	236	376

NOTE: Data Groups 240-372 were completed for SAMSO/AFFDL under ARO Project No. V41B-A4.

D. Rockwell Test OH-105

Model: 83-Ø

Nominal Mach No.: 8.0

ALPHA, DEG	YAW, DEG	DELTAE, DEG	DELTBF, DEG	DELTASB, DEG	RE/FT X 10^{-6}, 1/FT: 1.0		3.0		3.7	
				CONSTANT SET	911	922	911	922	911	922
					DATA GROUP NUMBERS					
0	0	0	0	0	424	425	432	433,440	415,416	417
10	↓	↓	↓	↓	426	427	434,441	435,442	418	419
15	↓	↓	↓	↓	428	429	436,443	437	420	421
20	↓	↓	↓	↓	430	431	438	439	422	423

TABLE 6. Continued

E. Rockwell Test OH-102

MODEL	CONFIG	MACH NO.	RE/FTX10^{-6}	ALPHA, DEG	YAW, DEG	DELTAE, DEG	DELTBF, DEG	DELTASB, DEG	CONSTANT SET 311	411	422	511	522	533
									DATA GROUP NUMBERS					
56-OTS	30	3.0	1.0	0	0	0	0	0	386,390					
				0	11				388					
				-5	0				387					
				-5	11				389					
			3.8	0	0				391					
					3				397					
					6				396					
					11				395					
				5	0				398					
				-5	0				392					
					6				393					
					11				394					
		4.0	1.0	0	0				399					
				0	11				401					
				-5	0				400					
				-5	11				402					
			4.0	0	0				403,410					
				0	3				407					
				0	6				408					
				0	11				409					
				5	0				406					
				-5	0				404					
				-5	6				405					
				-5	11				411					

TABLE 6. Continued

E. Rockwell Test OH-102

MODEL	CONFIG	MACH NO.	RE/FT X10^{-6}	ALPHA, DEG	YAW, DEG	DELTAE, DEG	DELTBF, DEG	DELTASB, DEG	CONSTANT SET 311	411	422	511	522	533
									DATA GROUP NUMBERS					
56-Ø	31	3.0	3.7	0	14.5	0	0	0	414					
	31	4.0	4.0	0	14.9				413					
60-OTS	60	3.0	1.0	0	0							494	495	496
				-5	0							497	498	499
				-5	6							500	501	502
			3.5	0	0							465	466	467
				0	3							493	475	476
				0	6							492	480	481
				0	11							488	486	487
				5	0							468	469	470
				-5	0							471	472	473
				-5	6							482	483	484
				-5	11							489	490	491
		4.0	1.0	0	0							512	515	516
				-5	0							514	517	518
				-5	6							519	520	521
			3.5	0	0							444	445	446
				0	3							505	454	455
				0	6							506	457	458
				0	11							507	503	504
				5	0							447	448	449
				-5	0							450	451	452
				-5	6							459	460	461
				-5	11							508	511	510

Delete Groups 412,453,456,462,463,464,474,477,478,479,485,509,513

TABLE 6. Concluded

E. Rockwell Test OH-102

MODEL	CONFIG	MACH NO.	RE/FT $X10^{-6}$, 1/FT	ALPHA, DEG	YAW, DEG	DELTAE, DEG	DELTBF, DEG	DELTASB, DEG	CONSTANT SET 311	411	422	511	522	533
									DATA GROUP NUMBERS					
60-Ø	50	3.0	1.0	0	0	0	0	0				531	532	533
			3.5	0	0							522	523	524
				0	14.5							525	526	527
				-14.5	0							528	529	530
		4.0	1.0	0	0								544	545
			3.5	0	0							534	535	536
				0	14.4							537	538	539
				-14.5	0							540	541	542
60-Ø	51	3.0	3.5	-40	0	0	0	0				546	547	548
		4.0	2.0	-40	0							553	554	555
			3.5	-30	0							549		
				-40	0							550	551	552
83-Ø	40	3.0	1.0	0	0	-	-	-		564	565			
				- 5	0					566	567			
			3.5	0	0					556	557			
				0	-6					560	561			
				- 5	0					558	559			
				- 5	-6					562	563			
		4.0	3.5	0	0					568	569			
				0	-6					572	573			
				- 5	0					570	571			
				- 5	-6					574	575			

Delete 543, 576

TABLE 7 60-Ø MODEL LOCAL SURFACE DEFLECTION ANGLES

T/c NO	ε, DEG	T/c NO	ε, DEG	T/c NO	ε, DEG	T/c NO	ε, DEG
1	90	21	2.0	41	-4.5	70	-4.5
2	50	22 C	1.4	42	-4.5	71	-4.5
3	35.5	23	1.0	43	-4.5	72	-4.5
4	23.0	24					
5	17.7	25		50 C	1.0	73 C	90.0
6	14.4	26		51 C		74 C	8.0
7	12.0	27 C		52 C		75 C	6.75
8	10.3	28 C		53 C		76 C	4.6
9	8.6	29 C		54 C		77 C	3.25
10	7.3	30 C		55 C		78 C	2.75
11	6.4	31 C				79 C	1.0
12	5.5	32 C		61 C	1.0	80 C	1.1
13	4.3	33 C		62 C		81 C	0.75
14	3.9	34 C	1.0	63 C		82 C	-0.5
15	3.6	35 C	-1.5	64 C		83	-5.7
16	3.4	36 C	-2.0	65 C		84	-8.0
17	3.1	37 C	-2.6	66 C	-2.0		
18	2.8	38 C	-3.2	67 C	-3.2		
19	2.6	39 C	-3.8	68 C	-3.8		
20	2.3	40	-4.5	69	-4.5		

TABLE 7 Concluded

T/c NO	ε, DEG	T/c NO	ε, DEG	T/c NO	ε, DEG	T/c NO	ε, DEG
86 C	90.0	106 C	0.6	127 C	4.5	148	-7.25
87 C	12.5	108 C	90.0	128 C	2.25	149	90.0
88 C	6.9	109 C	90.0	129 C	1.2	150	2.5
89 C	2.5	110 C	16.75	130 C	1.2	151	2.0
90 C	1.1	111 C	10.5	131	1.0	152	90.0
91 C	1.0	112 C	6.25	132	-7.5	153	3.75
92 C	1.6	113 C	4.0	133	90.0	154	3.0
93 C	1.1	114 C	1.5	134	18.0	155 C	2.25
94 C	0.2	115 C	1.5	135	9.0	157 C	1.75
95	-3.5	116 C	1.75	136	4.5	158	-3.0
96	-7.5	117 C	1.1	137	2.1	159	-7.75
97	-9.25	118 C	1.0	138	1.6	160	90.0
98 C	90.0	119 C	-0.5	139	1.5	161	8.5
99 C	90.0	120	-3.5	141 C	1.0	162	5.0
100 C	11.2	121	-4.6	142	-3.4	163	2.5
101 C	5.0	122	-8.0	143	-7.4	164	2.0
102 C	2.0	123	-9.25	144	-8.9	165	1.5
103 C	1.5	124 C	90.0	145	90.0	166	-0.5
104 C	1.25	125 C	90.0	146	2.0	167	-4.5
105 C	1.0	126 C	17.5	147	1.75	168	-7.5

TABLE 8

83-Ø MODEL LOCAL SURFACE DEFLECTION ANGLES

T/C NO	ϵ, DEG	T/C NO	ϵ, DEG
273	89.0	294	1.0
274	85.0	295	1.0
275	75.0		
276	43.0		
277	35.5		
279	23.0		
280	21.0		
281	20.0		
282	17.7		
283	16.5		
284	15.1		
285	14.1		
286	13.5		
287	12.0		
288	5.0		
289	3.4		
290	2.0		
291	1.0		
292	1.0		
293	1.0		

APPENDIX III

REFERENCE HEAT-TRANSFER CONDITIONS

In presenting heat-transfer coefficient results, it is convenient to use reference coefficients to normalize the data. Equilibrium stagnation point values derived from the work of Fay and Riddell* were used to normalize the data obtained in this test. These reference coefficients are given by:

$$\mathrm{HREF} = \frac{8.17173(\mathrm{PO2})^{0.5}\,(\mathrm{MUO})^{0.4}\left[1 - \frac{(\mathrm{P\text{-}INF})}{\mathrm{PO2}}\right]^{0.25}\left[0.2235+(1.35\mathrm{x}10^{5})(\mathrm{TO}+560)\right]}{(\mathrm{RN})^{0.5}\,(\mathrm{TO})^{0.15}}$$

$$\mathrm{STFR} = \frac{\mathrm{HREF}}{(\mathrm{RHO\text{-}INF})\,(\mathrm{V\text{-}INF})\left[0.2235 + 1.35 \times 10^{-5}\,(\mathrm{TO} + 560)\right]}$$

*Fay, J. A., and Riddell, F. R., "Theory of Stagnation Point Heat Transfer in Dissociated Air," Journal of the Aeronautical Sciences, Vol. 25, No. 2, February 1958.

APPENDIX IV

SAMPLE TABULATED AND PLOTTED DATA

ARO, INC. - AEDC DIVISION
A SVERDR[illegible] [illegible]ORPORATION COMPANY
VON KARMA[illegible] GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE

DATE COMP[illegible]D 25-JUN-79
TIME COMP[illegible]D 10:46:03
DATE RECORDED 18-MAY-79
TIME RECORDED 20:14:26
PROJECT NUMBER V41B-67

NASA/RI OH-84B HEATING TEST

GROUP	CONSTANT	MODEL	MACH NO	PO,PSIA	TO,DEGR	ALPHA-PREBEND	ALPHA-SECTOR	ROLL-SECTOR	ALPHA-MODEL	YAW
579	SET 211	60-0	7.99	670.8	1324.7	30.00	-10.02	0.06	40.02	-0.01

T-INF (DEGR)	P-INF (PSIA)	Q-INF (PSIA)	V-INF (FT/SEC)	RHO-INF (LBM/FT3)	MU-INF (LB-SEC/FT2)	RE/FT (FT-1)	HREF-FR (RN= 0.0175FT)	STFR (RN= 0.0175FT)	SWITCH POSITION	CONFIG
96.21	0.069	3.096	3842.	1.943E-03	7.742E-08	2.997E+06	4.353E-02	2.342E-02	1	20

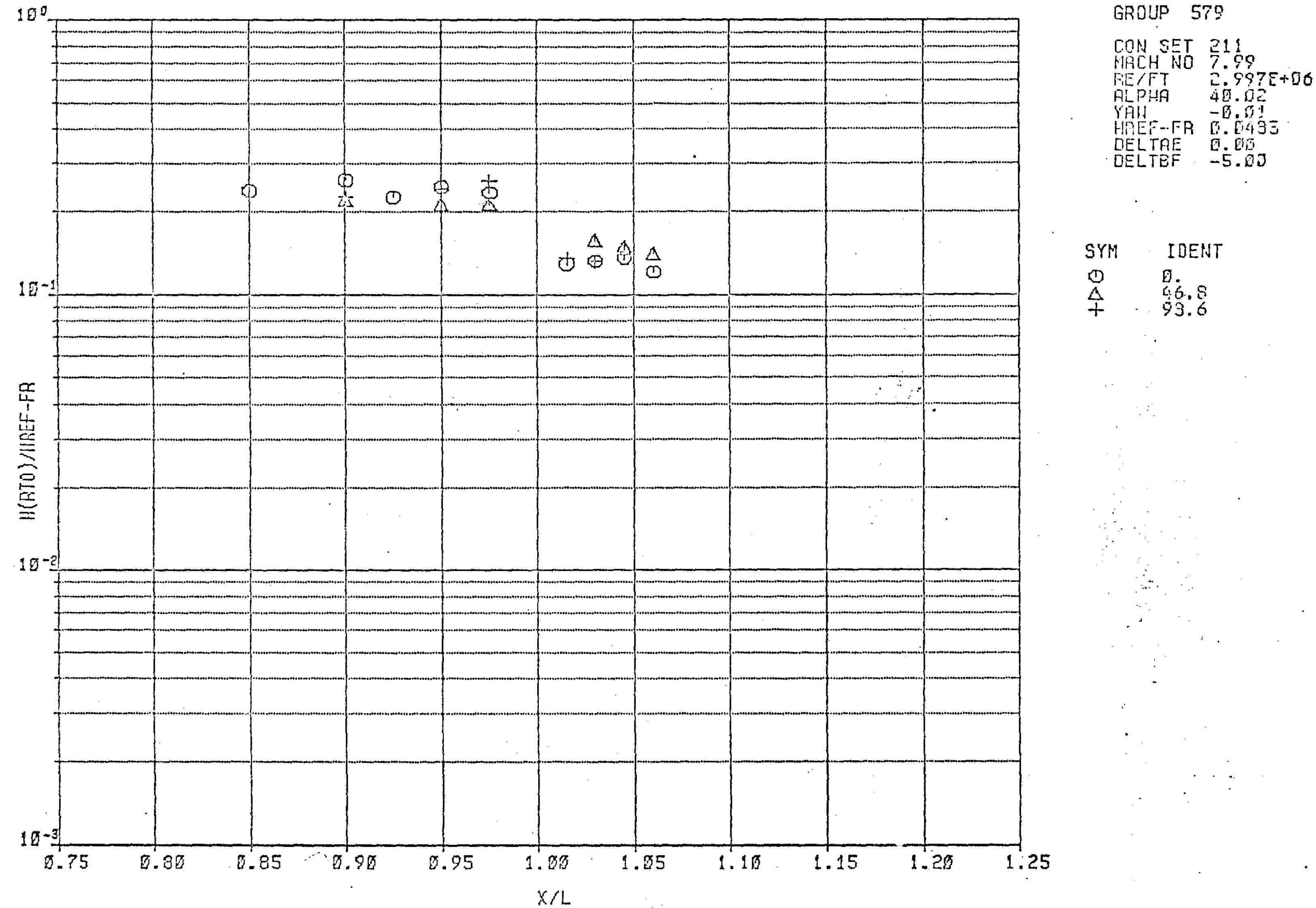
DELTAE	DELTBF	DELTASB
0.0	-5.0	0.0

TC NO	TW (DEGR)	DTWDT (DEG/S)	QDOT (BTU/ FT2-S)	H(TO) (BTU/FT2 S-DEGR)	H(TO)/ HREF	H(.90TO) (BTU-FT2- S-DEGR)	H(.90TO)/ HREF	R	H(RTO) (BTU-FT2- S-DEGR)	H(RTO)/ HREF	COORD1	COORD2	SKIN THICK NESS
60	576.0	26.779	3.786	5.057E-03	0.1162	6.144E-03	0.1412	0.9000	6.144E-03	0.1412	1.0600	46.8000	0.0310
69	584.5	29.833	3.758	5.077E-03	0.1167	6.184E-03	0.1421	0.9243	5.873E-03	0.1349	1.0150	93.6000	0.0275
70	580.5	28.346	3.693	4.963E-03	0.1140	6.038E-03	0.1387	0.9243	5.736E-03	0.1318	1.0300	93.6000	0.0285
71	581.5	29.712	3.941	5.303F-03	0.1218	6.453E-03	0.1483	0.9243	6.130E-03	0.1408	1.0450	93.6000	0.0290
72	DELETE												
164	605.5	34.717	4.981	6.926E-03	0.1591	8.490E-03	0.1951	0.9384	7.813E-03	0.1795	0.3000	444.9000	0.0310
165	599.2	27.099	3.751	5.170E-03	0.1188	6.325E-03	0.1453	0.9373	5.838E-03	0.1341	0.5000	444.9000	0.0300
166	599.5	44.285	6.028	8.312E-03	0.1910	1.017E-02	0.2337	0.9330	9.471E-03	0.2176	0.7000	444.9000	0.0295
167	602.6	51.743	7.174	9.935E-03	0.2283	1.217E-02	0.2795	0.9243	1.154E-02	0.2651	0.8000	444.9000	0.0300
168	597.4	47.608	6.474	8.902E-03	0.2045	1.088E-02	0.2501	0.9178	1.047E-02	0.2405	0.9000	444.9000	0.0295
156	608.6	31.998	4.598	6.421E-03	0.1475	7.878E-03	0.1810	0.9000	7.878E-03	0.1810	0.5000	421.4000	0.0310
158	611.8	60.715	8.033	1.127E-02	0.2589	1.384E-02	0.3180	0.9276	1.302E-02	0.2991	0.8000	421.4000	0.0285
159	603.8	60.179	7.792	1.081E-02	0.2484	1.324E-02	0.3043	0.9173	1.275E-02	0.2929	0.9000	421.4000	0.0280
146	604.8	40.384	5.979	8.306E-03	0.1908	1.018E-02	0.2339	0.9384	9.368E-03	0.2152	0.2000	374.6000	0.0320
147	602.6	30.097	4.312	5.971E-03	0.1372	7.313E-03	0.1680	0.9379	6.740E-03	0.1548	0.4000	374.6000	0.0310
148	593.2	55.287	7.757	1.061E-02	0.2437	1.295E-02	0.2975	0.9184	1.245E-02	0.2859	0.9000	374.6000	0.0305
138	595.1	29.722	4.790	6.566E-03	0.1508	8.022E-03	0.1843	0.9375	7.405E-03	0.1701	0.3000	352.8000	0.0350
139	595.2	26.859	4.205	5.764E-03	0.1324	7.044E-03	0.1618	0.9373	6.505E-03	0.1494	0.4000	352.8000	0.0340
140	594.5	25.905	3.935	5.390E-03	0.1238	6.584E-03	0.1513	0.9000	6.584E-03	0.1513	0.6000	352.8000	0.0330
142	609.6	54.224	6.789	9.494E-03	0.2181	1.165E-02	0.2677	0.9267	1.099E-02	0.2524	0.8000	352.8000	0.0270
314 A	537.3	0.091	0.010	1.322E-05	0.0003	1.589E-05	0.0004	0.9000	1.589E-05	0.0004	1.0230	0.0000	0.0255
315 A	539.0	2.324	0.198	2.516E-04	0.0058	3.027E-04	0.0070	0.9000	3.027E-04	0.0070	1.0560	0.0000	0.0190
316 A	537.5	0.198	0.026	3.313E-05	0.0008	3.983E-05	0.0009	0.9000	3.983E-05	0.0009	1.0230	0.8750	0.0295
317 A	538.3	2.249	0.282	3.585E-04	0.0082	4.311E-04	0.0099	0.9000	4.311E-04	0.0099	1.0560	0.8750	0.0280
318 A	537.7	0.532	0.070	8.919E-05	0.0020	1.072E-04	0.0025	0.9000	1.072E-04	0.0025	1.0230	1.8370	0.0295
319 A	536.9	1.082	0.143	1.812E-04	0.0042	2.178E-04	0.0050	0.9000	2.178E-04	0.0050	1.0560	1.6970	0.0295
113 A	583.3	27.525	3.780	5.098E-03	0.1171	6.207E-03	0.1426	0.9000	6.207E-03	0.1426	1.0230	0.9280	0.0300
191 A	576.8	21.786	2.783	3.722E-03	0.0855	4.523E-03	0.1039	0.9000	4.523E-03	0.1039	1.0230	1.8190	0.0280
192 A	561.9	18.158	2.549	3.342E-03	0.0768	4.045E-03	0.0929	0.9000	4.045E-03	0.0929	1.0110	5.0640	0.0310
193 A	558.4	14.330	1.976	2.579E-03	0.0592	3.118E-03	0.0716	0.9000	3.118E-03	0.0716	1.0230	5.0920	0.0305
194 A	549.7	11.248	1.570	2.025E-03	0.0465	2.443E-03	0.0561	0.9000	2.443E-03	0.0561	1.0390	5.1060	0.0310
186 A	602.7	41.265	5.721	7.924E-03	0.1821	9.705E-03	0.2230	0.9000	9.705E-03	0.2230	0.8930	1.8190	0.0300
187 A	591.7	32.158	4.582	6.252E-03	0.1436	7.631E-03	0.1753	0.9000	7.631E-03	0.1753	0.9200	1.8830	0.0310

Tabulated Data

ARO, INC(AEDC)
ARNOLD AFS, TN
DATE 05/02/79
V41B-67

NASA/RI



Plotted Data